U. S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
WASHINGTON, DC 20231
IF UNDELIVERABLE RETURN IN TEN DAYS

OFFICIAL BUSINESS

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES POSTAGE
PITNEY
02 1A
0004202245
$ 0
JUL
MAILED FROM ZIP COD

LIVERABLE
S ADDRESSED,
UNABLE TO FORWAR

2/3

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/895,905	06/29/2001	Jens A. Roever	US 018092	9484

7590 07/23/2004

Corporate Patent Counsel
U.S. Philips Corporation
580 White Plains Road
Tarrytown, NY 10591

EXAMINER	
ALAVI, AMIR	

ART UNIT	PAPER NUMBER
2621	

DATE MAILED: 07/23/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

RECEIVED
AUG 0 3 2004
Technology Center 2600

US006055071A

United States Patent [19]

Kuwata et al.

[11] Patent Number: 6,055,071

[45] Date of Patent: *Apr. 25, 2000

[54] IMAGE FORMING APPARATUS

[75] Inventors: Kazumi Kuwata, Tokyo; Kouji Hayashi, Kanagawa, both of Japan

[73] Assignee: Ricoh Company, Ltd., Tokyo, Japan

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

[21] Appl. No.: 08/854,111

[22] Filed: May 9, 1997

[30] **Foreign Application Priority Data**

May 10, 1996	[JP]	Japan	8-116723
Nov. 8, 1996	[JP]	Japan	8-296542
Apr. 25, 1997	[JP]	Japan	9-109257

[51] **Int. Cl.**[7] **H04N 1/00**

[52] **U.S. Cl.** **358/501**; 358/521

[58] **Field of Search** 358/518, 443, 358/523, 520, 455, 501; 382/169, 167

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,194,945	3/1993	Kadowaki et al.	358/520
5,508,826	4/1996	Lloyd et al.	358/501
5,585,927	12/1996	Fukui et al.	358/523
5,754,683	5/1998	Hayashi et al.	358/518
5,764,378	6/1998	Oda et al.	358/443
5,767,991	6/1998	Hara	358/518

FOREIGN PATENT DOCUMENTS

0 674 429 A2	9/1995	European Pat. Off.	
0 685 962 A2	12/1995	European Pat. Off.	
63-208370	8/1988	Japan	
63-303370	12/1988	Japan	
5-114962	5/1993	Japan	H04N 1/00
7-193686	7/1995	Japan	
7-298075	11/1995	Japan	

Primary Examiner—Yon J. Couso
Attorney, Agent, or Firm—McDermott, Will & Emery

[57] **ABSTRACT**

An image forming apparatus according to the present invention comprises a scanner for optically scanning and reading a draft image, an image processing circuit for converting input image signals from this scanner to output image signals by referring to an image signal conversion table and outputting the converted signals, a laser optical system for writing image information on a photosensitive drum in response to the output image signals, developing units for forming images with toner, an image signal generating means for generating a plurality of gradation patterns, and a CPU which prepares and selectors an image signal conversion table according to read signals for gradation patterns read by the scanner; wherein a read signal for a gradation pattern comprises a plurality of signals with different spectral sensitivity respectively, and said image forming apparatus has a RAM to store calibration factors for the plurality of factors with different spectral sensitivity respectively and calibrates read signals according to a calibration factor from the RAM.

12 Claims, 27 Drawing Sheets

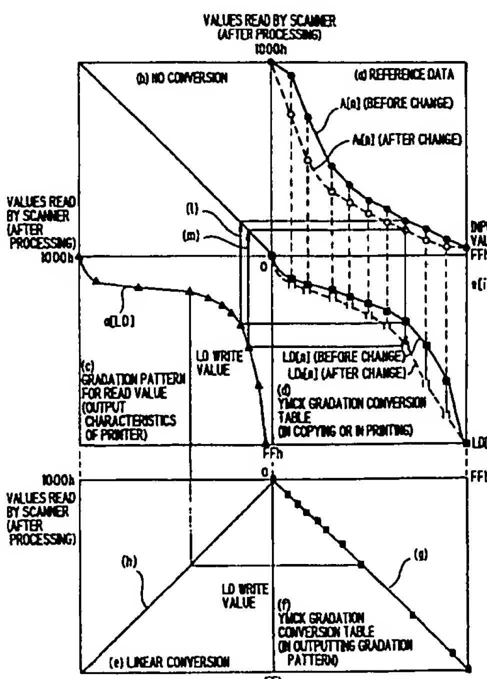


FIG.1

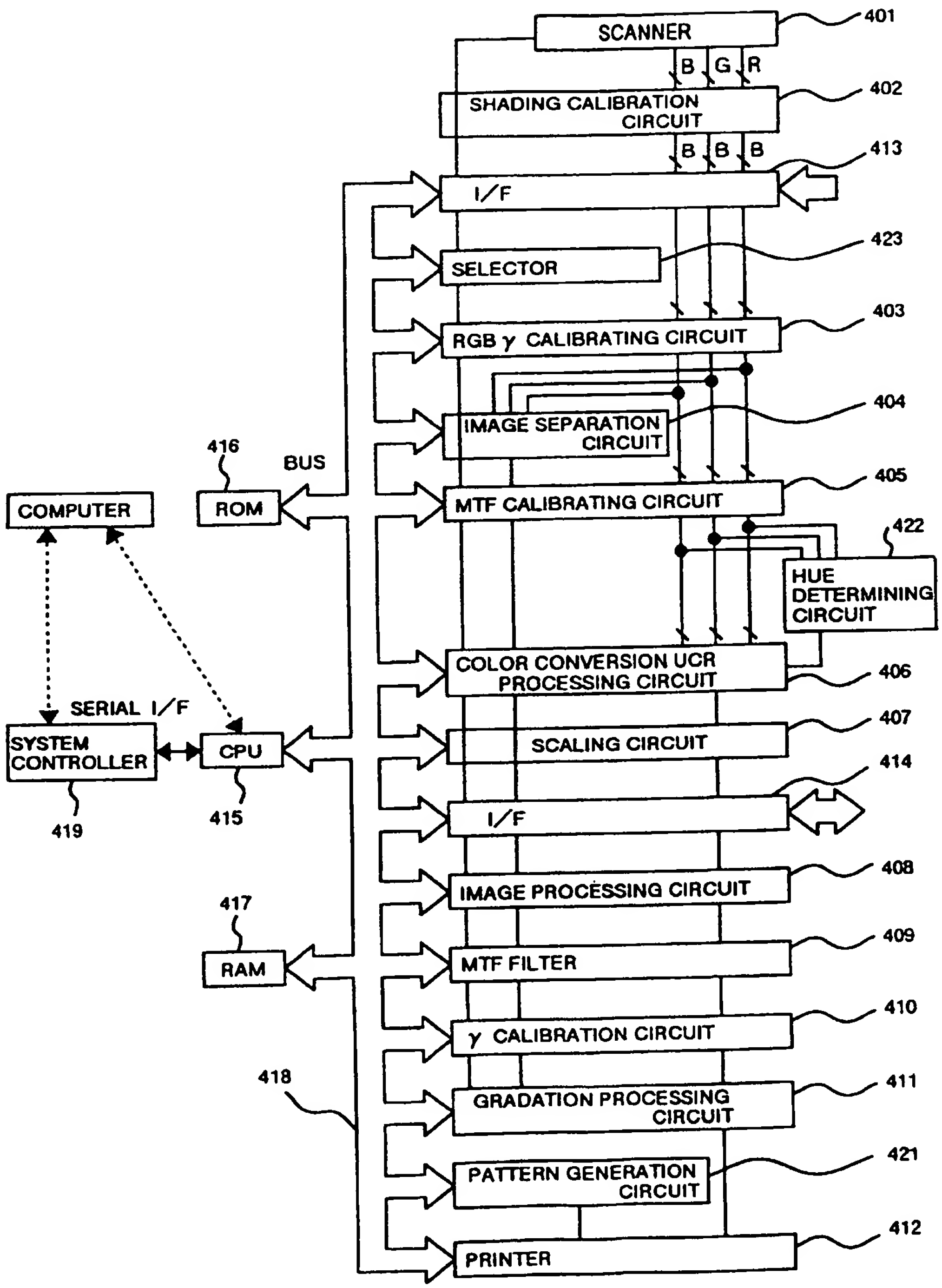

SCANNER
401
B
G
R
SHADING CALIBRATION CIRCUIT
402
B
B
B
413
I/F
SELECTOR
423
RGB γ CALIBRATING CIRCUIT
403
IMAGE SEPARATION CIRCUIT
404
416
BUS
MTF CALIBRATING CIRCUIT
405
COMPUTER
ROM
422
HUE DETERMINING CIRCUIT
COLOR CONVERSION UCR PROCESSING CIRCUIT
406
SERIAL I/F
SYSTEM CONTROLLER
CPU
SCALING CIRCUIT
407
414
419
415
I/F
IMAGE PROCESSING CIRCUIT
408
417
RAM
MTF FILTER
409
γ CALIBRATION CIRCUIT
410
418
GRADATION PROCESSING CIRCUIT
411
PATTERN GENERATION CIRCUIT
421
PRINTER
412

FIG.2

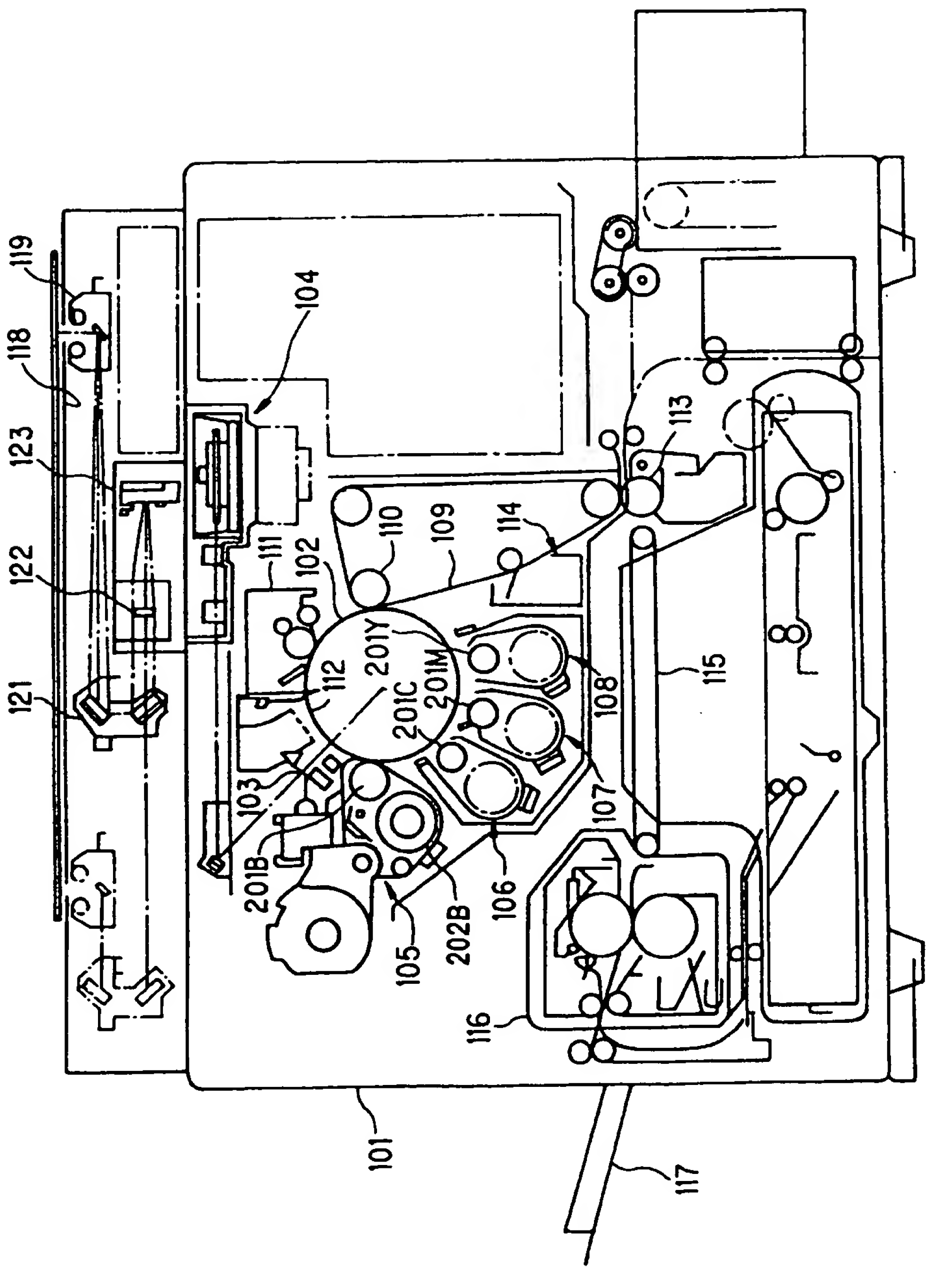

119
118
123
122
121
104
111
102
110
109
114
113
112
201Y
201C
201M
108
115
107
106
103
201B
202B
105
116
101
117

FIG.3

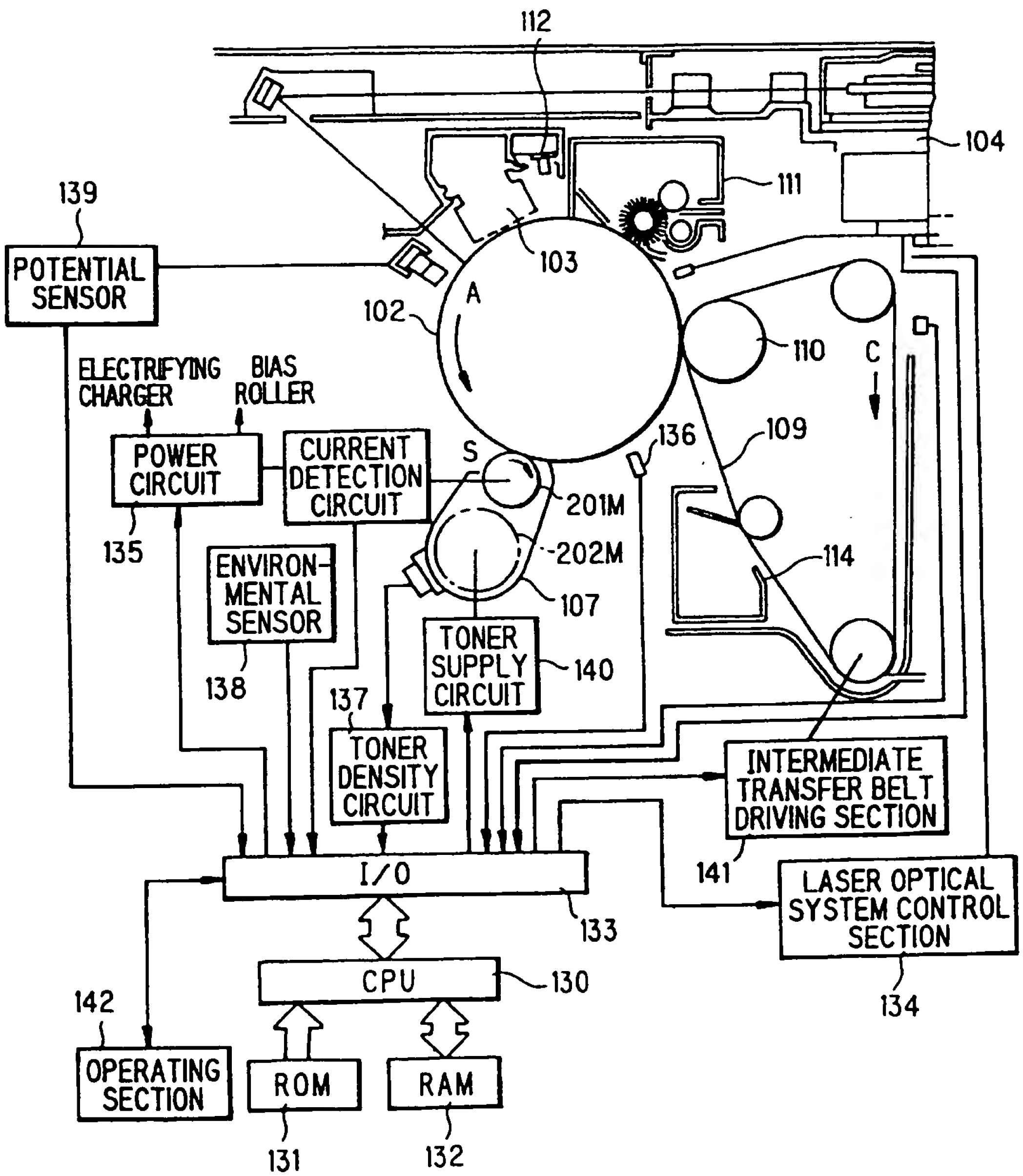

112
104
111
139
POTENTIAL SENSOR
103
102
A
110
C
ELECTRIFYING CHARGER
BIAS ROLLER
POWER CIRCUIT
CURRENT DETECTION CIRCUIT
S
136
109
201M
202M
135
ENVIRON-MENTAL SENSOR
114
107
TONER SUPPLY CIRCUIT
140
138
137
TONER DENSITY CIRCUIT
INTERMEDIATE TRANSFER BELT DRIVING SECTION
141
I/O
LASER OPTICAL SYSTEM CONTROL SECTION
133
CPU
130
134
142
OPERATING SECTION
ROM
RAM
131
132

FIG.4

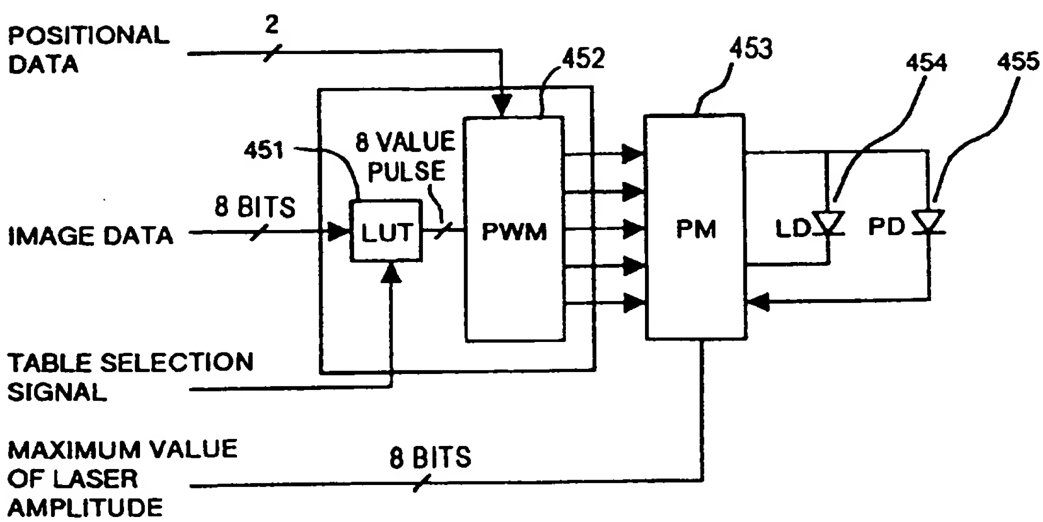

POSITIONAL DATA
2
452
453
454
455
451
8 VALUE PULSE
8 BITS
IMAGE DATA
LUT
PWM
PM
LD
PD
TABLE SELECTION SIGNAL
MAXIMUM VALUE OF LASER AMPLITUDE
8 BITS

FIG.5

PREPARATION OF GRADATION CONVERSION CURVE

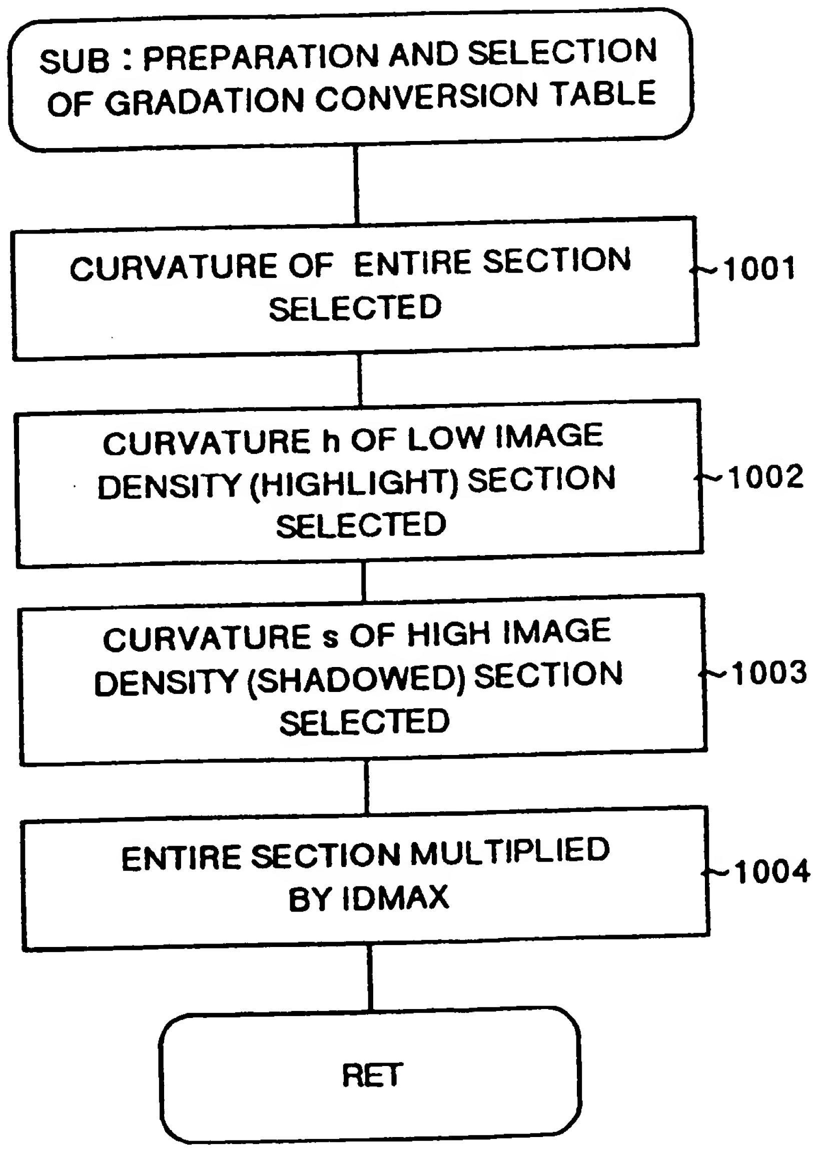


FIG.6

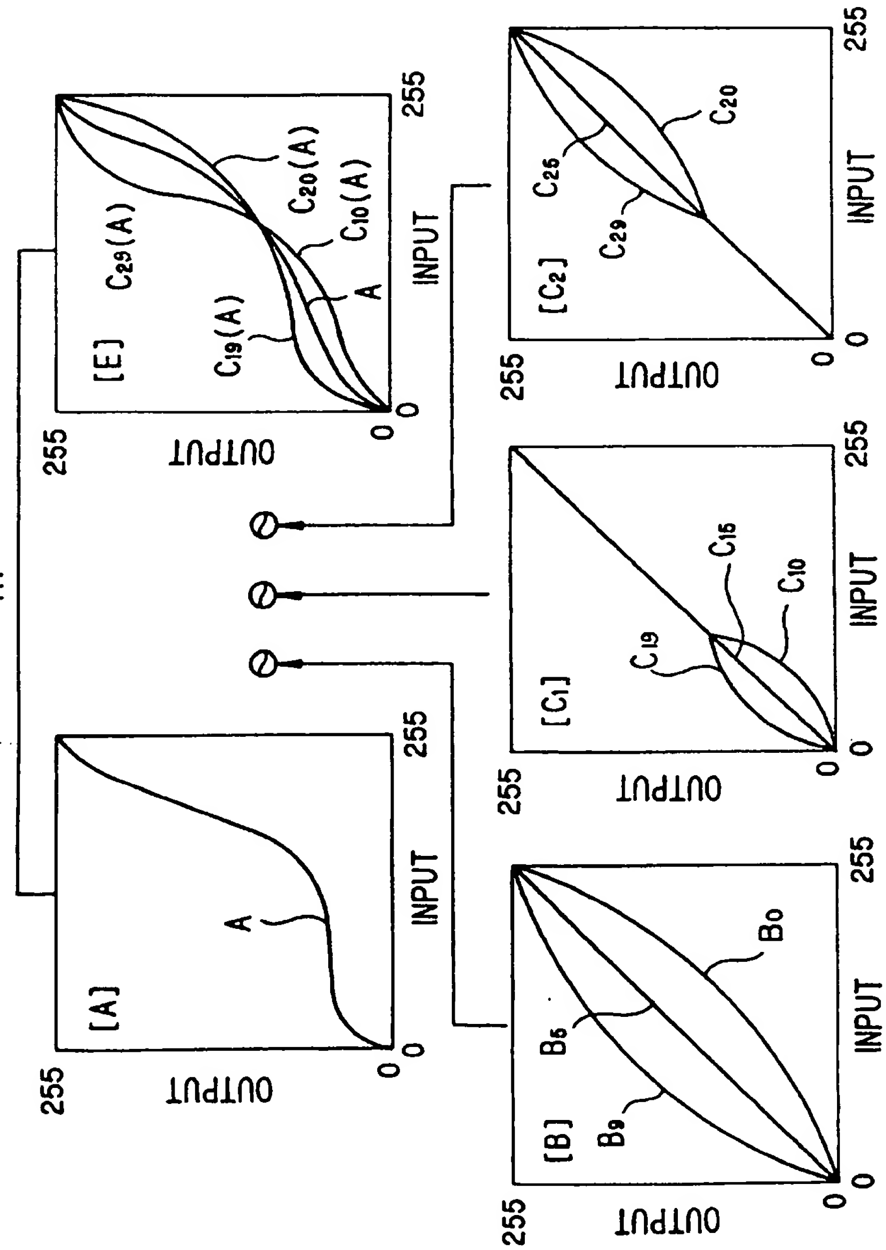

A1
[A]
A
[E]
$C_{29}(A)$
$C_{20}(A)$
$C_{10}(A)$
$C_{19}(A)$
[B]
B_9
B_5
B_0
[C_1]
C_{19}
C_{15}
C_{10}
[C_2]
C_{25}
C_{29}
C_{20}
OUTPUT
INPUT
255
0

FIG.7

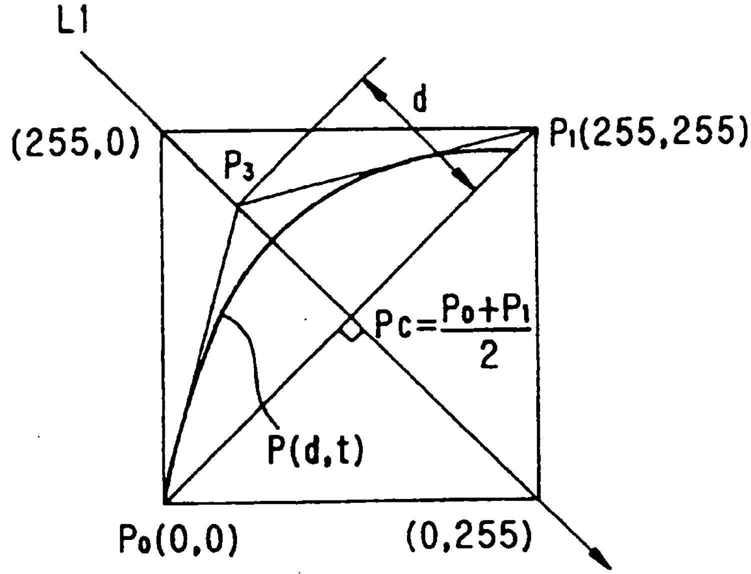

L1
d
(255,0)
P_1(255,255)
P_3
$Pc=\frac{P_0+P_1}{2}$
P(d,t)
P_0(0,0)
(0,255)

FIG.8

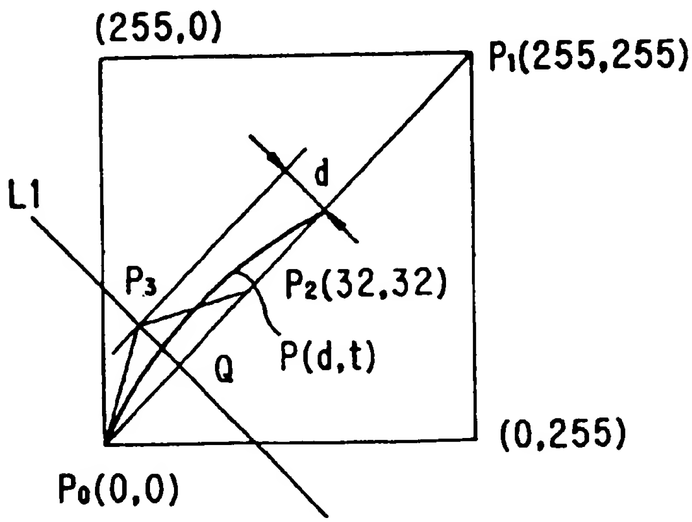
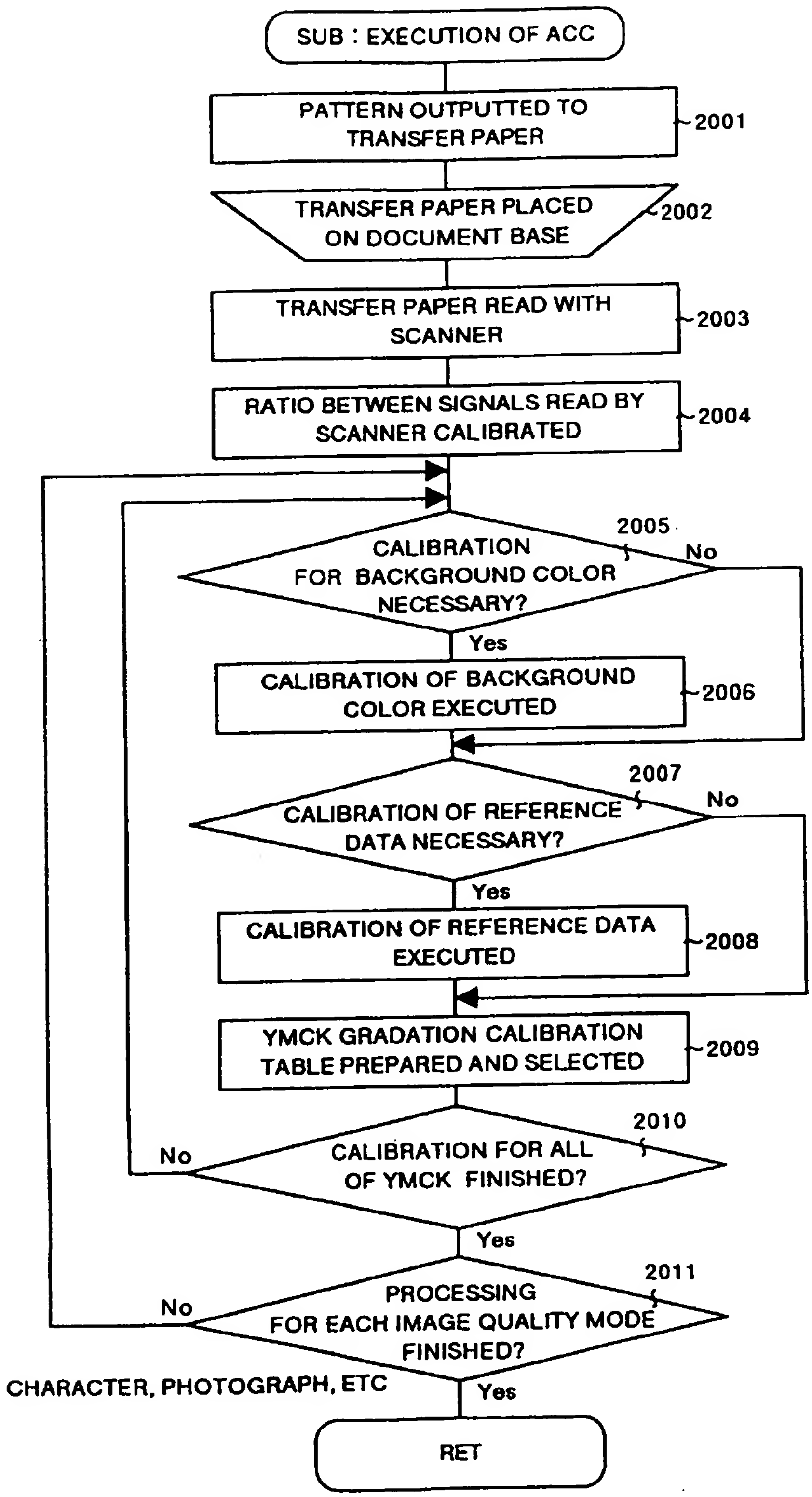

(255,0)
P_1(255,255)
d
L1
P_3
P_2(32,32)
P(d,t)
Q
(0,255)
P_0(0,0)

FIG.9


SUB : EXECUTION OF ACC
PATTERN OUTPUTTED TO TRANSFER PAPER
2001
TRANSFER PAPER PLACED ON DOCUMENT BASE
2002
TRANSFER PAPER READ WITH SCANNER
2003
RATIO BETWEEN SIGNALS READ BY SCANNER CALIBRATED
2004
CALIBRATION FOR BACKGROUND COLOR NECESSARY?
2005
No
Yes
CALIBRATION OF BACKGROUND COLOR EXECUTED
2006
CALIBRATION OF REFERENCE DATA NECESSARY?
2007
No
Yes
CALIBRATION OF REFERENCE DATA EXECUTED
2008
YMCK GRADATION CALIBRATION TABLE PREPARED AND SELECTED
2009
CALIBRATION FOR ALL OF YMCK FINISHED?
2010
No
Yes
PROCESSING FOR EACH IMAGE QUALITY MODE FINISHED?
2011
No
CHARACTER, PHOTOGRAPH, ETC
Yes
RET

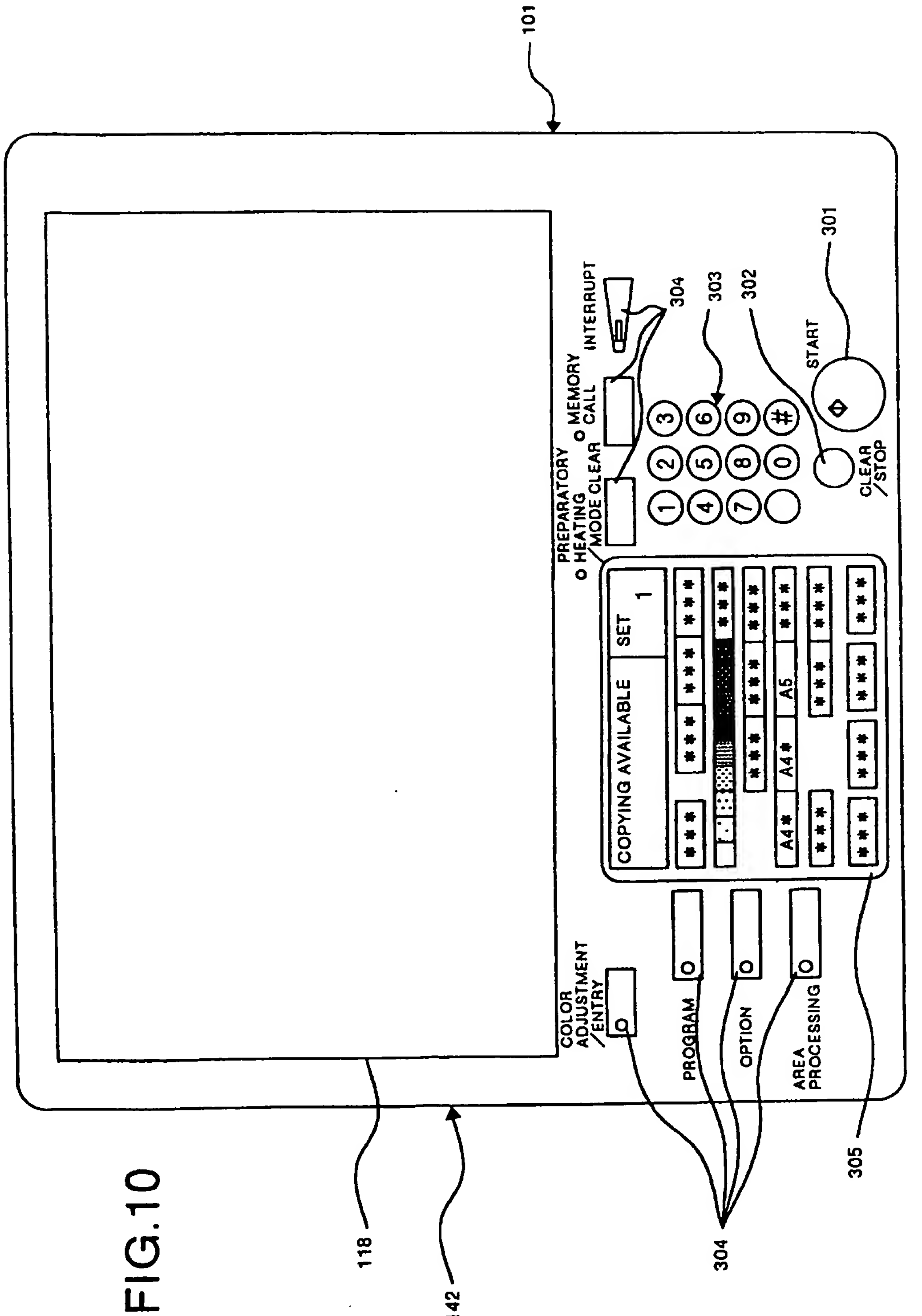

101
INTERRUPT
304
303
302
301
MEMORY CALL
PREPARATORY HEATING MODE CLEAR
START
CLEAR /STOP
COPYING AVAILABLE
SET
1
A5
A4
A4
COLOR ADJUSTMENT /ENTRY
PROGRAM
OPTION
AREA PROCESSING
305
304
118
142

FIG.10

FIG.11

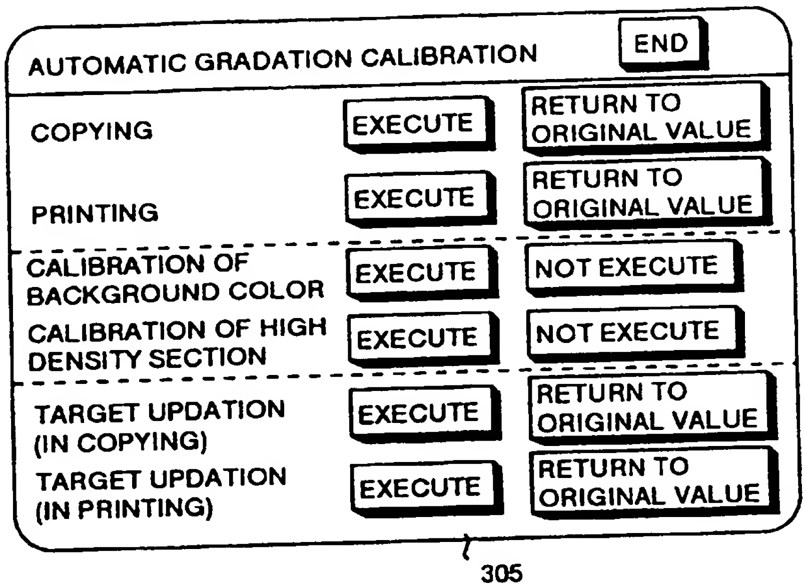

AUTOMATIC GRADATION CALIBRATION
END
COPYING
EXECUTE
RETURN TO ORIGINAL VALUE
PRINTING
EXECUTE
RETURN TO ORIGINAL VALUE
CALIBRATION OF BACKGROUND COLOR
EXECUTE
NOT EXECUTE
CALIBRATION OF HIGH DENSITY SECTION
EXECUTE
NOT EXECUTE
TARGET UPDATION (IN COPYING)
EXECUTE
RETURN TO ORIGINAL VALUE
TARGET UPDATION (IN PRINTING)
EXECUTE
RETURN TO ORIGINAL VALUE
305

FIG.12

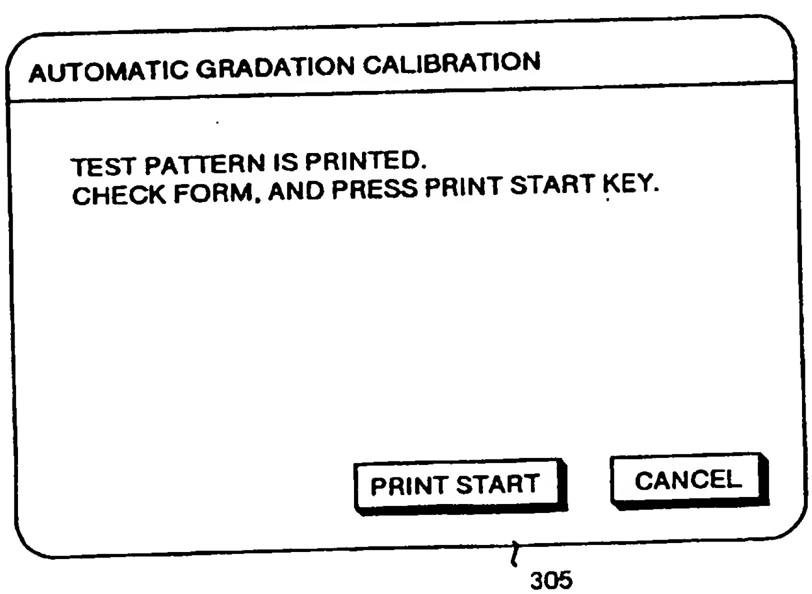

AUTOMATIC GRADATION CALIBRATION
TEST PATTERN IS PRINTED.
CHECK FORM, AND PRESS PRINT START KEY.
PRINT START
CANCEL
305

FIG.13

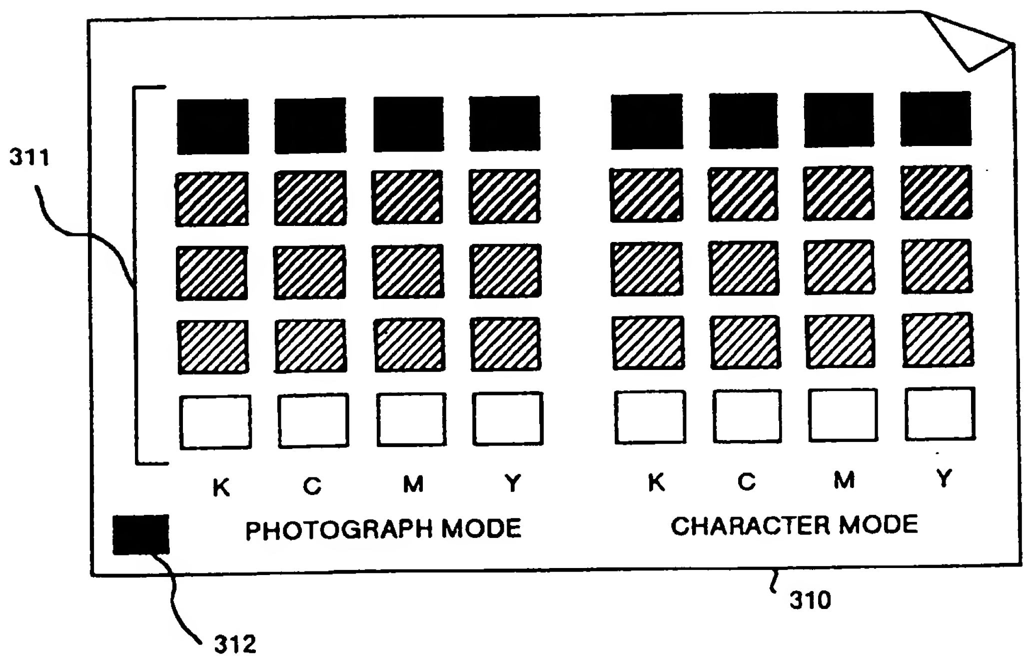


FIG.14

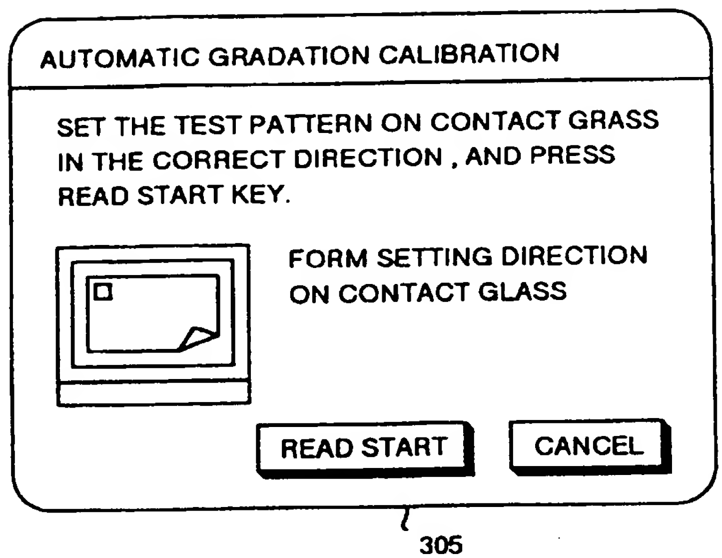

AUTOMATIC GRADATION CALIBRATION
SET THE TEST PATTERN ON CONTACT GRASS IN THE CORRECT DIRECTION , AND PRESS READ START KEY.
FORM SETTING DIRECTION ON CONTACT GLASS
READ START
CANCEL
305

FIG.15

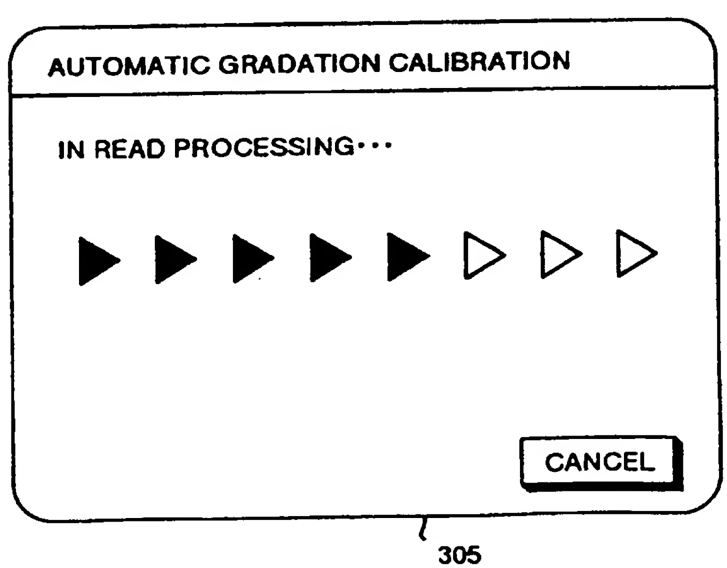

AUTOMATIC GRADATION CALIBRATION
IN READ PROCESSING···
CANCEL
305

FIG.16

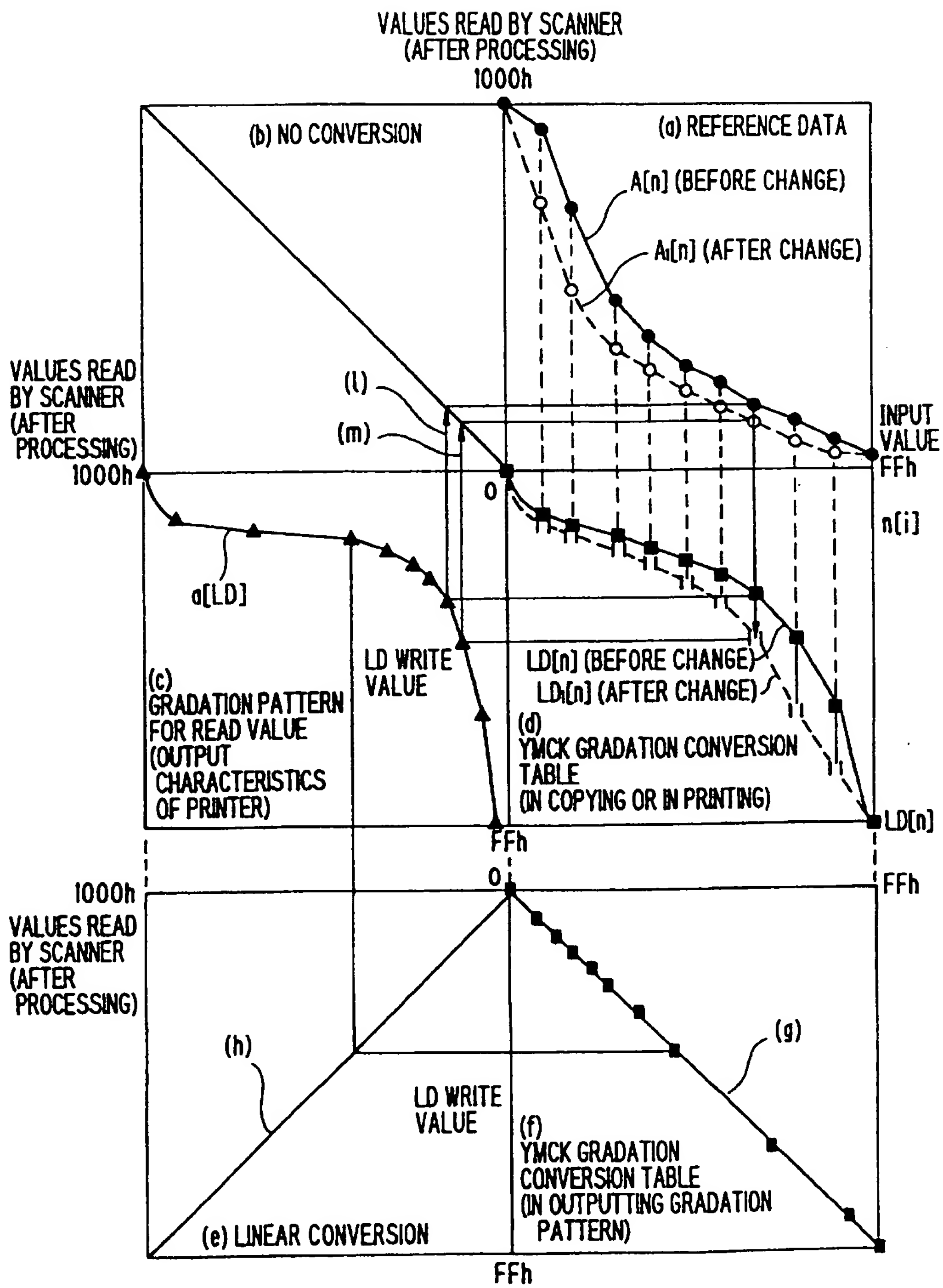

VALUES READ BY SCANNER (AFTER PROCESSING)
1000h
(b) NO CONVERSION
(a) REFERENCE DATA
A[n] (BEFORE CHANGE)
A1[n] (AFTER CHANGE)
VALUES READ BY SCANNER (AFTER PROCESSING)
1000h
(l)
(m)
INPUT VALUE
FFh
0
n[i]
a[LD]
LD WRITE VALUE
LD[n] (BEFORE CHANGE)
LD1[n] (AFTER CHANGE)
(c) GRADATION PATTERN FOR READ VALUE (OUTPUT CHARACTERISTICS OF PRINTER)
(d) YMCK GRADATION CONVERSION TABLE (IN COPYING OR IN PRINTING)
LD[n]
FFh
0
FFh
1000h
VALUES READ BY SCANNER (AFTER PROCESSING)
(h)
(g)
LD WRITE VALUE
(f) YMCK GRADATION CONVERSION TABLE (IN OUTPUTTING GRADATION PATTERN)
(e) LINEAR CONVERSION
FFh

FIG.17

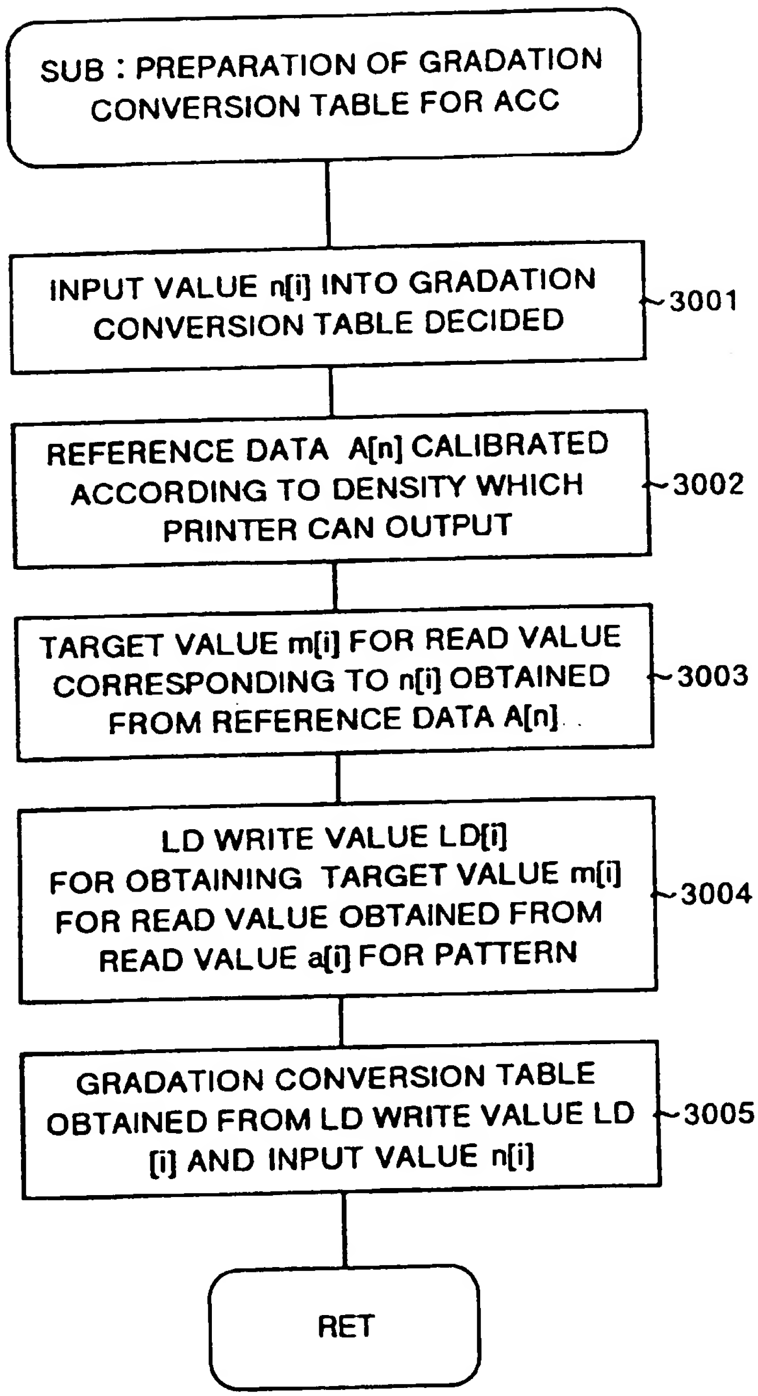

SUB : PREPARATION OF GRADATION CONVERSION TABLE FOR ACC
INPUT VALUE n[i] INTO GRADATION CONVERSION TABLE DECIDED
3001
REFERENCE DATA A[n] CALIBRATED ACCORDING TO DENSITY WHICH PRINTER CAN OUTPUT
3002
TARGET VALUE m[i] FOR READ VALUE CORRESPONDING TO n[i] OBTAINED FROM REFERENCE DATA A[n]
3003
LD WRITE VALUE LD[i] FOR OBTAINING TARGET VALUE m[i] FOR READ VALUE OBTAINED FROM READ VALUE a[i] FOR PATTERN
3004
GRADATION CONVERSION TABLE OBTAINED FROM LD WRITE VALUE LD [i] AND INPUT VALUE n[i]
3005
RET

FIG.18

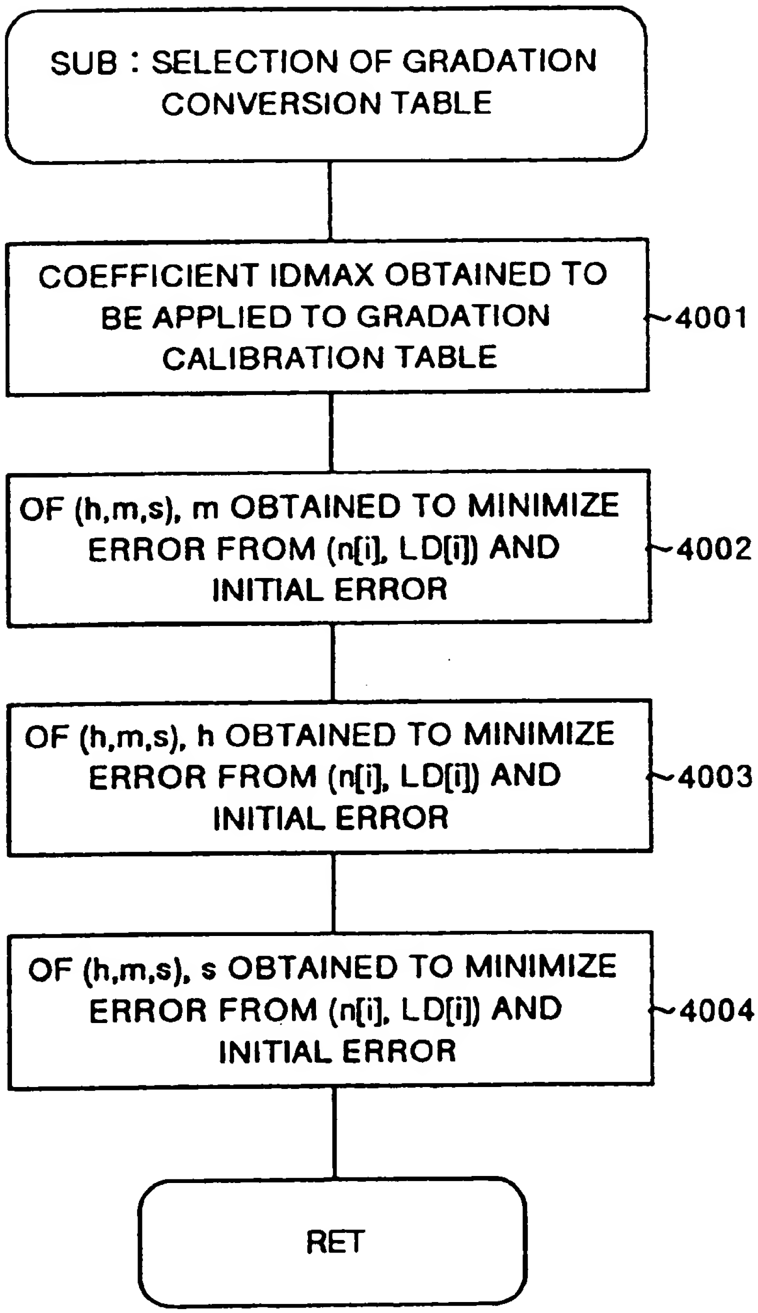

SUB : SELECTION OF GRADATION CONVERSION TABLE
COEFFICIENT IDMAX OBTAINED TO BE APPLIED TO GRADATION CALIBRATION TABLE
4001
OF (h,m,s), m OBTAINED TO MINIMIZE ERROR FROM (n[i], LD[i]) AND INITIAL ERROR
4002
OF (h,m,s), h OBTAINED TO MINIMIZE ERROR FROM (n[i], LD[i]) AND INITIAL ERROR
4003
OF (h,m,s), s OBTAINED TO MINIMIZE ERROR FROM (n[i], LD[i]) AND INITIAL ERROR
4004
RET

FIG.19

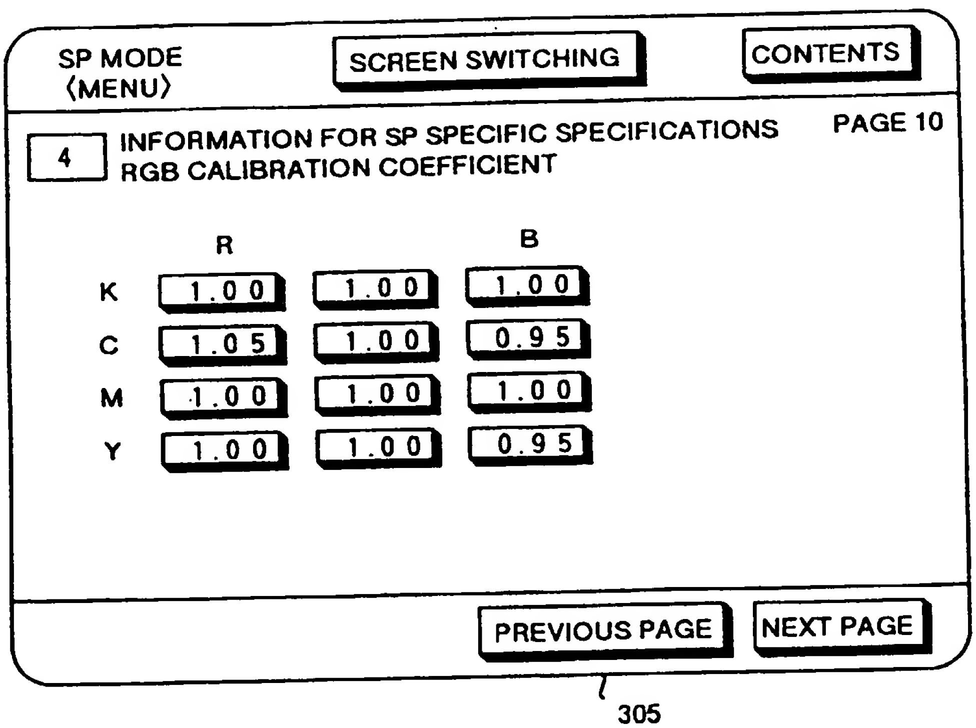

SP MODE
(MENU)
SCREEN SWITCHING
CONTENTS
4
INFORMATION FOR SP SPECIFIC SPECIFICATIONS
RGB CALIBRATION COEFFICIENT
PAGE 10
R
B
K
C
M
Y
1.00
1.00
1.00
1.05
1.00
0.95
1.00
1.00
1.00
1.00
1.00
0.95
PREVIOUS PAGE
NEXT PAGE
305

FIG.20

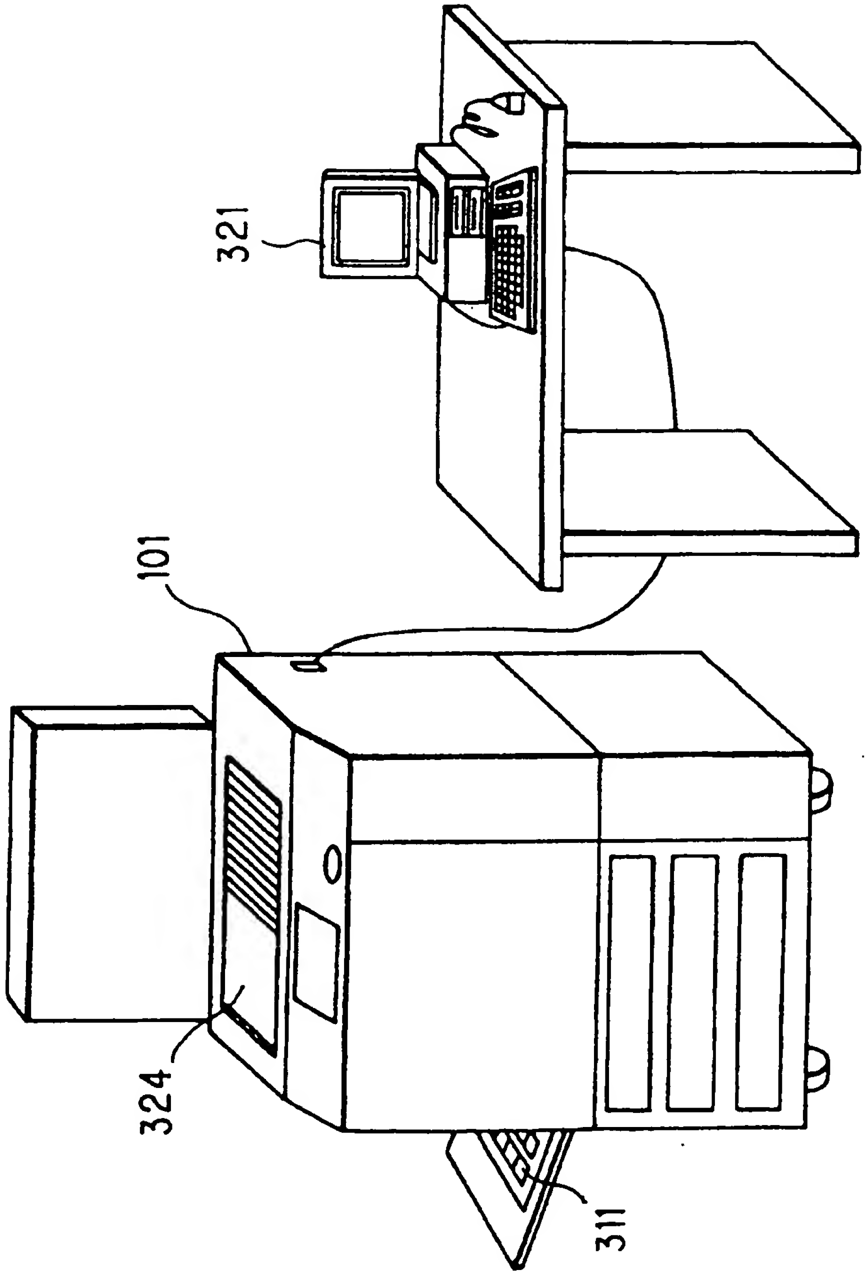


FIG.21

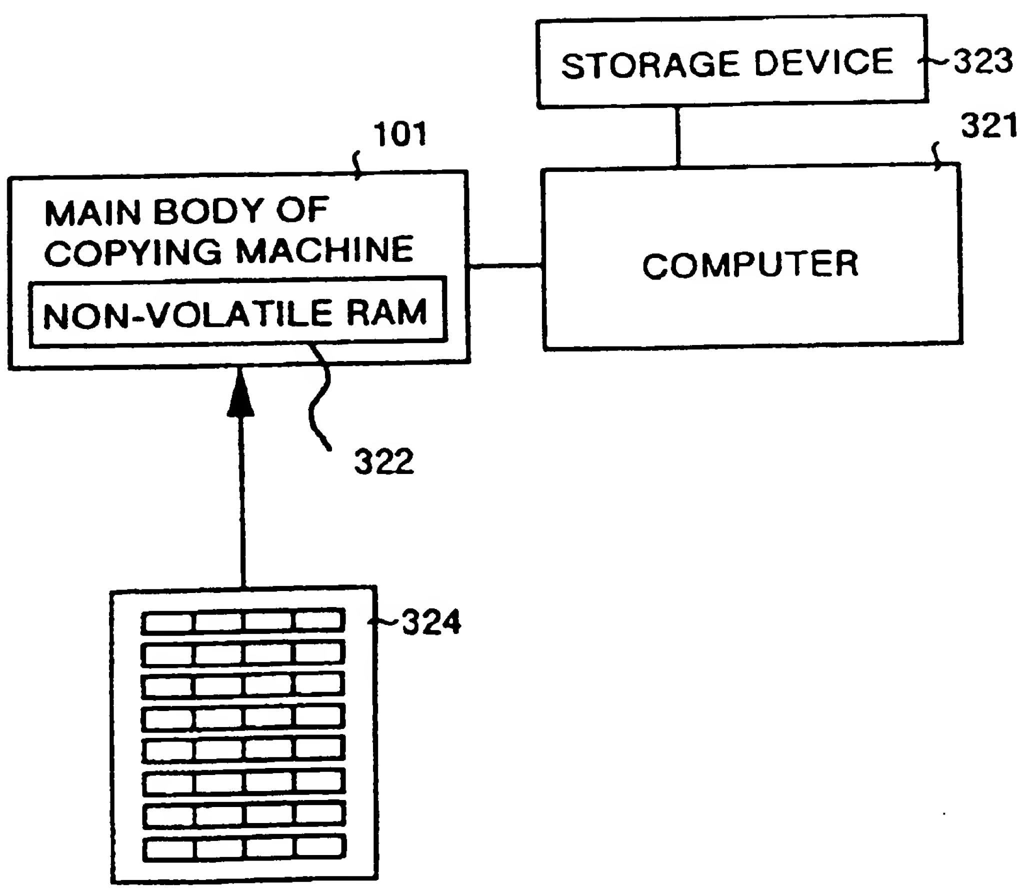

STORAGE DEVICE
323
321
101
MAIN BODY OF COPYING MACHINE
NON-VOLATILE RAM
COMPUTER
322
324

FIG.22

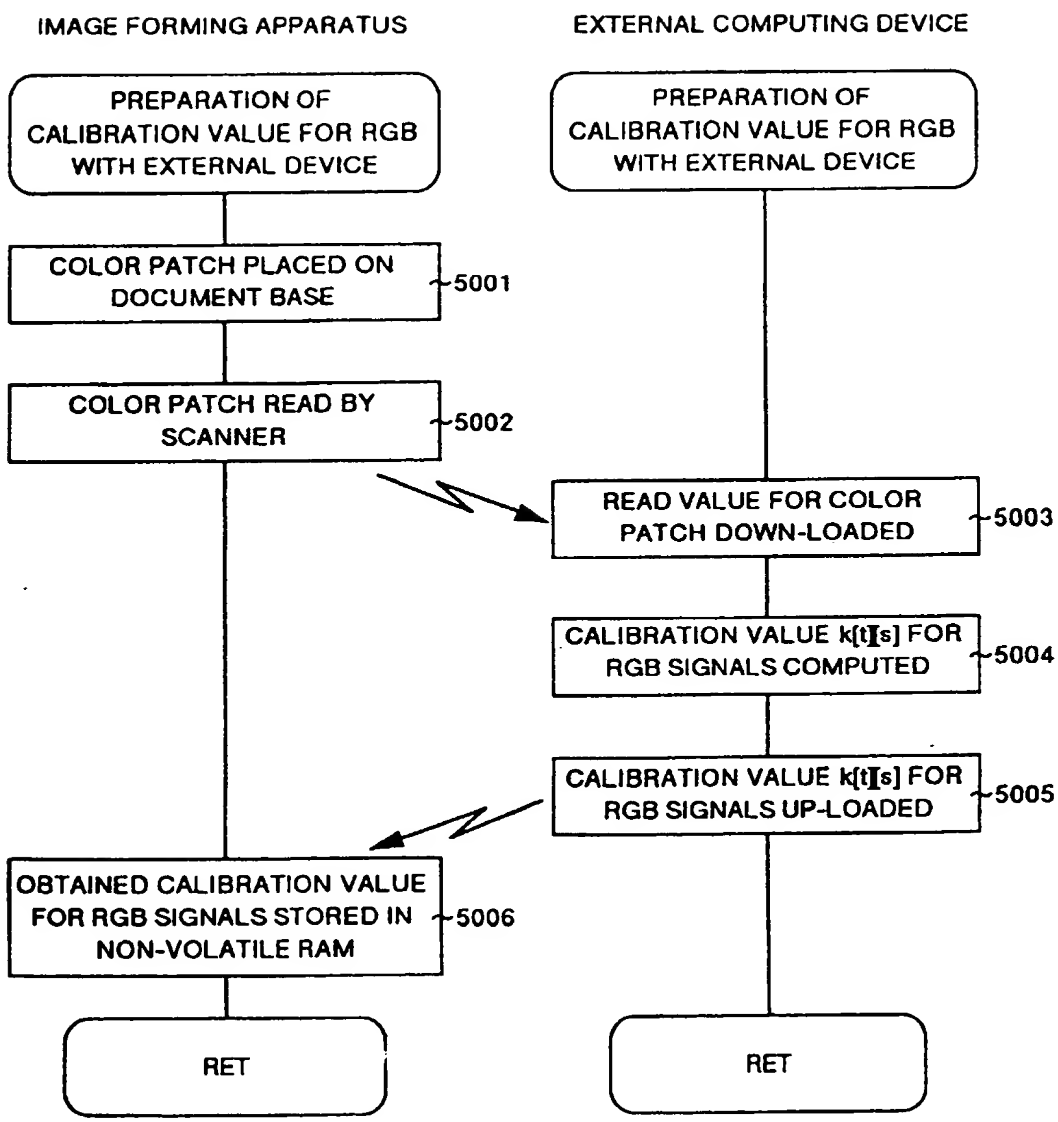


IMAGE FORMING APPARATUS
EXTERNAL COMPUTING DEVICE
PREPARATION OF CALIBRATION VALUE FOR RGB WITH EXTERNAL DEVICE
PREPARATION OF CALIBRATION VALUE FOR RGB WITH EXTERNAL DEVICE
COLOR PATCH PLACED ON DOCUMENT BASE
5001
COLOR PATCH READ BY SCANNER
5002
READ VALUE FOR COLOR PATCH DOWN-LOADED
5003
CALIBRATION VALUE k[t][s] FOR RGB SIGNALS COMPUTED
5004
CALIBRATION VALUE k[t][s] FOR RGB SIGNALS UP-LOADED
5005
OBTAINED CALIBRATION VALUE FOR RGB SIGNALS STORED IN NON-VOLATILE RAM
5006
RET
RET

FIG.23

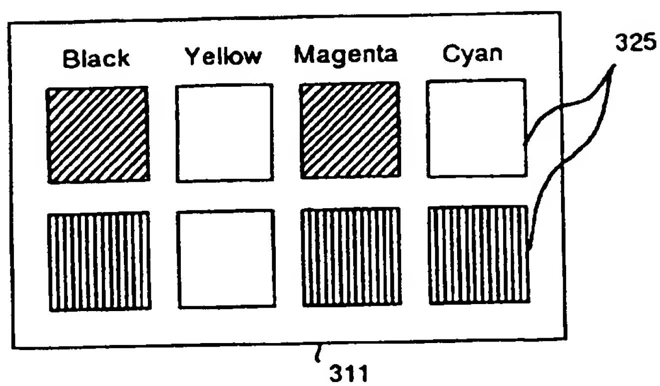

Black
Yellow
Magenta
Cyan
325
311

FIG.24

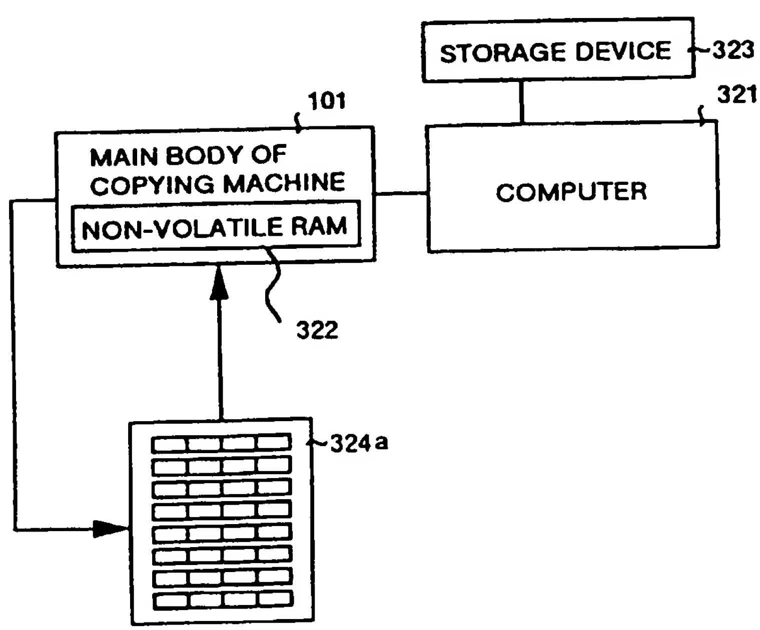

STORAGE DEVICE
323
321
101
MAIN BODY OF COPYING MACHINE
NON-VOLATILE RAM
COMPUTER
322
324a

FIG.25

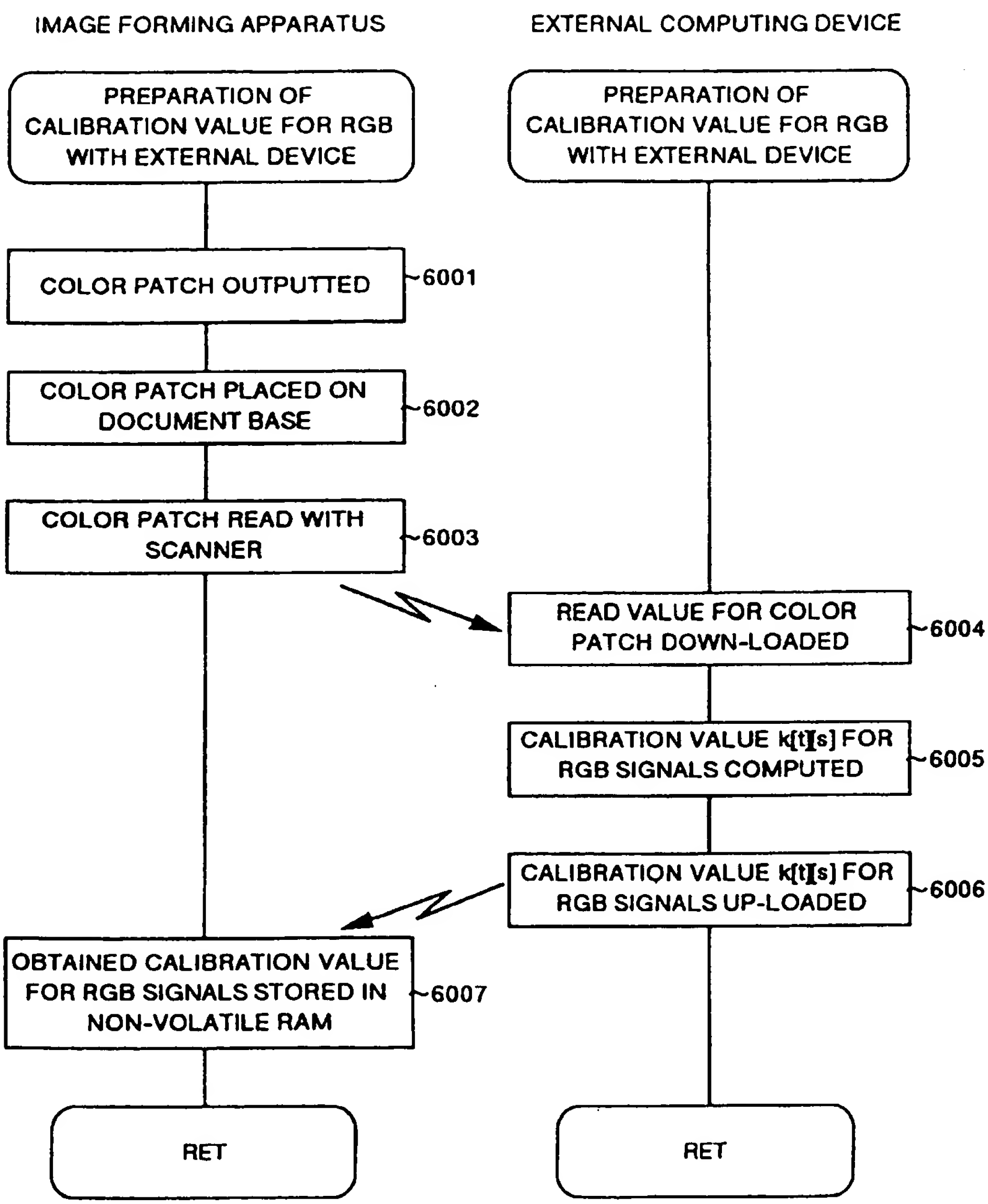


IMAGE FORMING APPARATUS
EXTERNAL COMPUTING DEVICE
PREPARATION OF CALIBRATION VALUE FOR RGB WITH EXTERNAL DEVICE
PREPARATION OF CALIBRATION VALUE FOR RGB WITH EXTERNAL DEVICE
COLOR PATCH OUTPUTTED
6001
COLOR PATCH PLACED ON DOCUMENT BASE
6002
COLOR PATCH READ WITH SCANNER
6003
READ VALUE FOR COLOR PATCH DOWN-LOADED
6004
CALIBRATION VALUE k[t][s] FOR RGB SIGNALS COMPUTED
6005
CALIBRATION VALUE k[t][s] FOR RGB SIGNALS UP-LOADED
6006
OBTAINED CALIBRATION VALUE FOR RGB SIGNALS STORED IN NON-VOLATILE RAM
6007
RET
RET

FIG.26

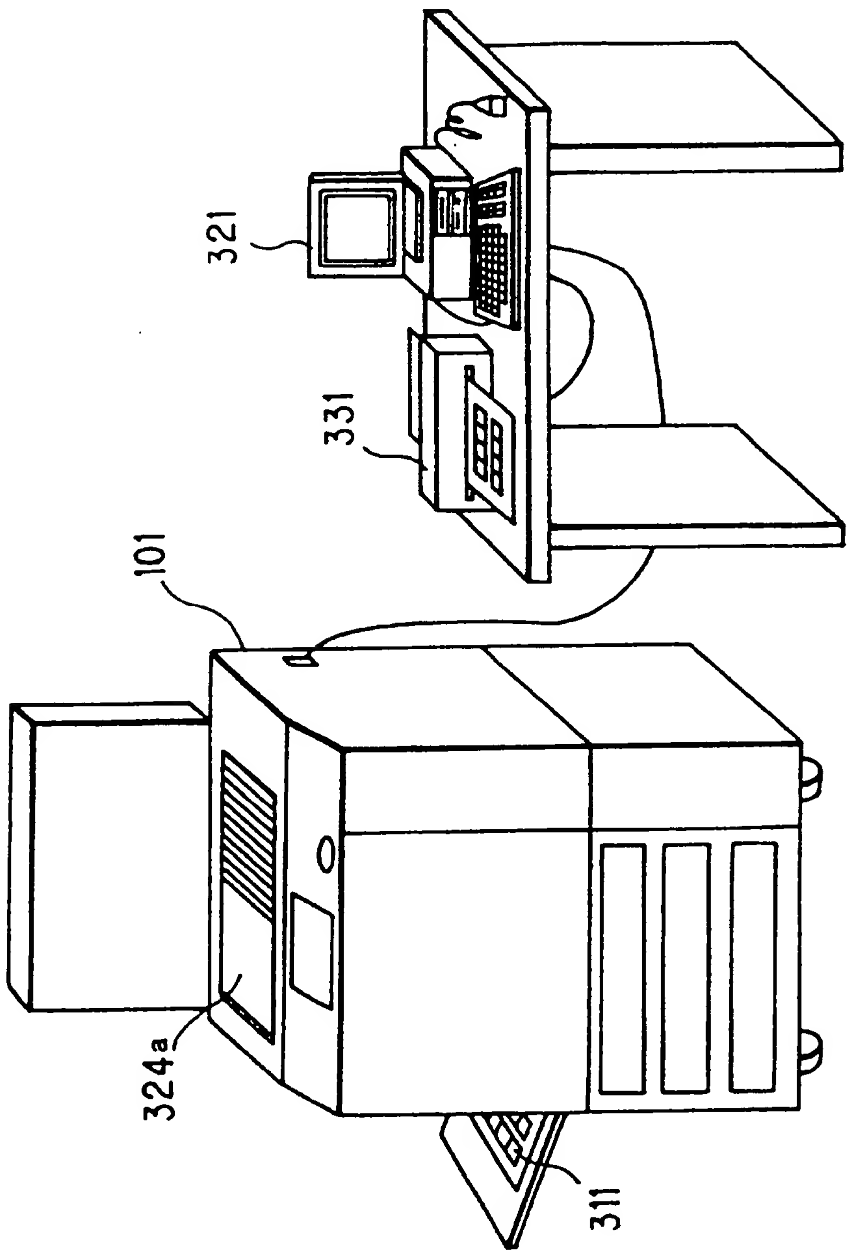


FIG.27

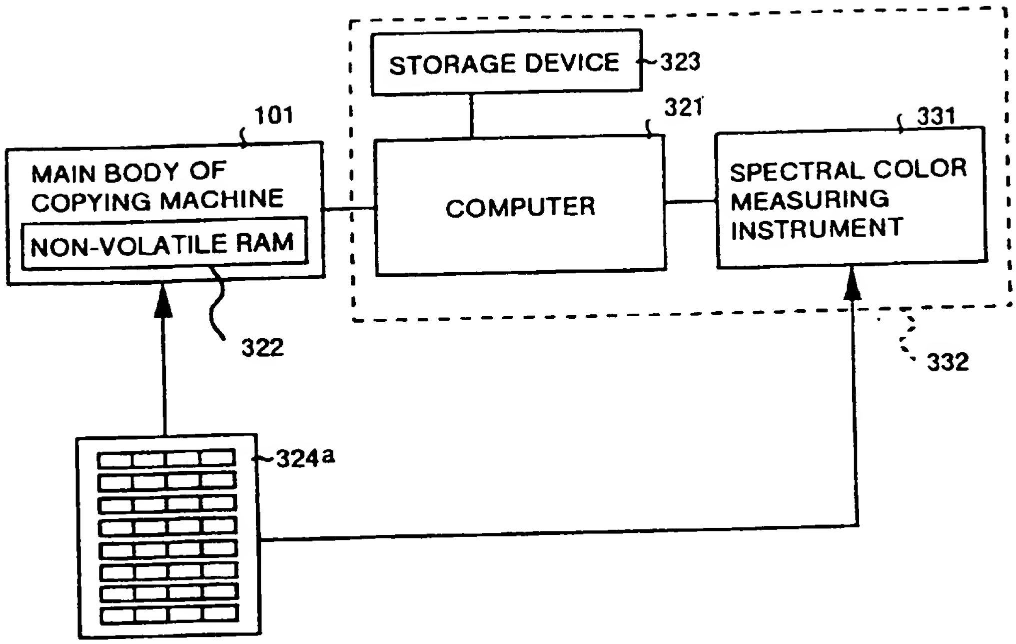

STORAGE DEVICE
323
321
101
331
MAIN BODY OF COPYING MACHINE
NON-VOLATILE RAM
COMPUTER
SPECTRAL COLOR MEASURING INSTRUMENT
322
332
324a

FIG.28

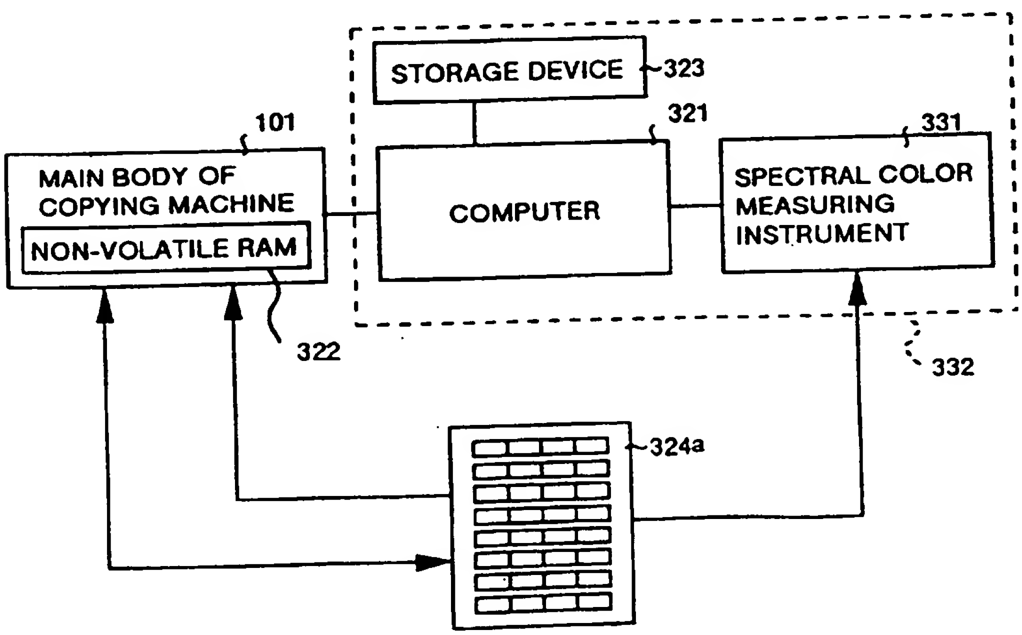

STORAGE DEVICE
323
321
101
331
MAIN BODY OF COPYING MACHINE
NON-VOLATILE RAM
COMPUTER
SPECTRAL COLOR MEASURING INSTRUMENT
322
332
324a

FIG.29

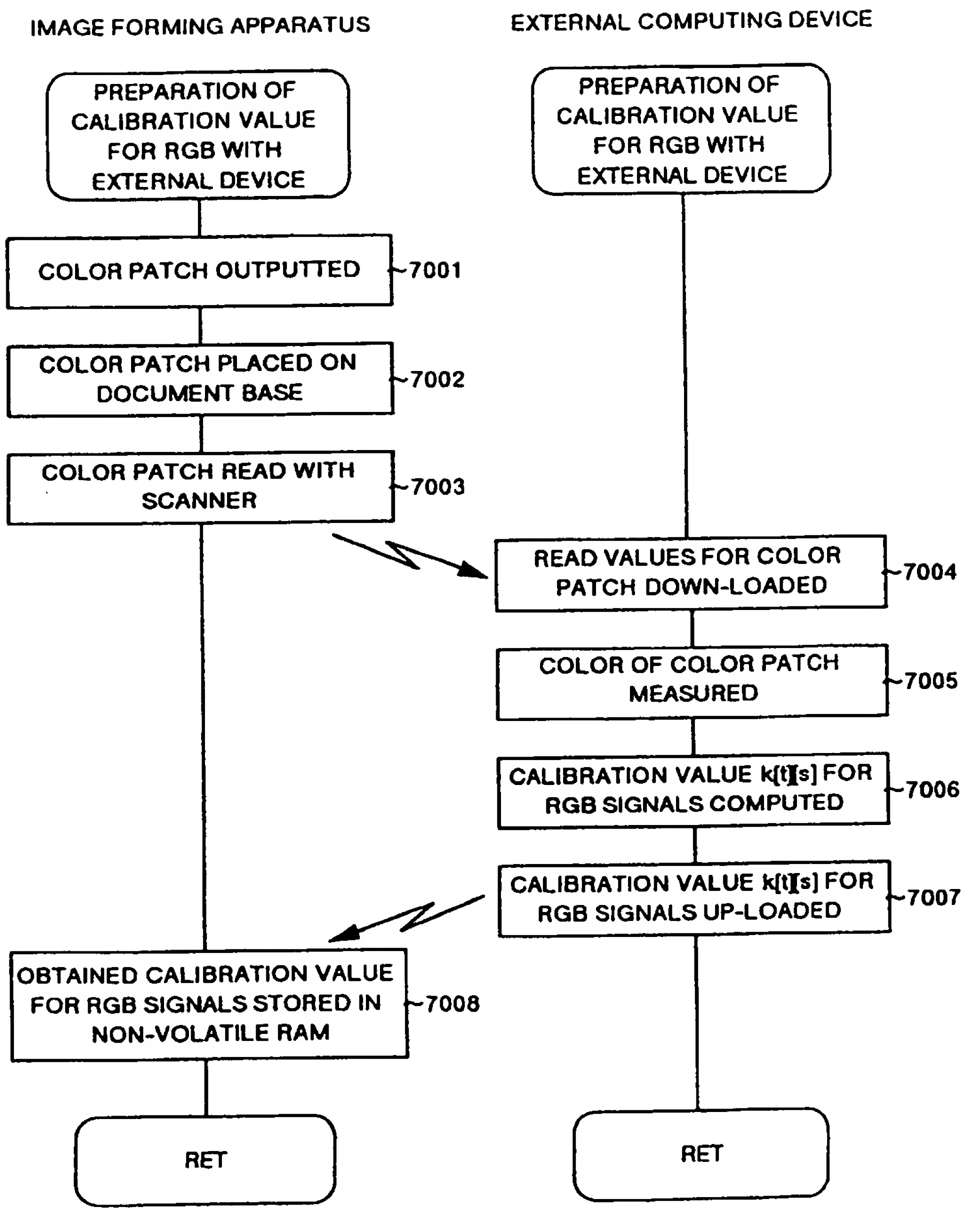


IMAGE FORMING APPARATUS
EXTERNAL COMPUTING DEVICE
PREPARATION OF CALIBRATION VALUE FOR RGB WITH EXTERNAL DEVICE
PREPARATION OF CALIBRATION VALUE FOR RGB WITH EXTERNAL DEVICE
COLOR PATCH OUTPUTTED
7001
COLOR PATCH PLACED ON DOCUMENT BASE
7002
COLOR PATCH READ WITH SCANNER
7003
READ VALUES FOR COLOR PATCH DOWN-LOADED
7004
COLOR OF COLOR PATCH MEASURED
7005
CALIBRATION VALUE k[t][s] FOR RGB SIGNALS COMPUTED
7006
CALIBRATION VALUE k[t][s] FOR RGB SIGNALS UP-LOADED
7007
OBTAINED CALIBRATION VALUE FOR RGB SIGNALS STORED IN NON-VOLATILE RAM
7008
RET
RET

FIG.30

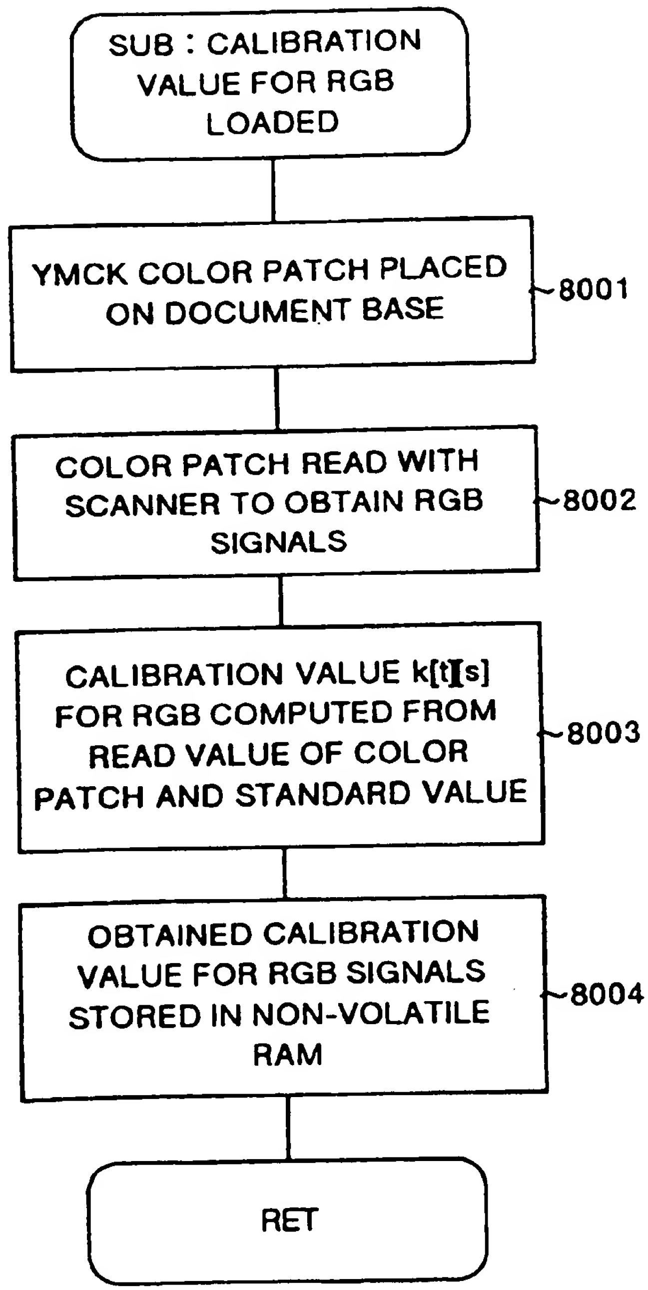

SUB : CALIBRATION VALUE FOR RGB LOADED
YMCK COLOR PATCH PLACED ON DOCUMENT BASE
8001
COLOR PATCH READ WITH SCANNER TO OBTAIN RGB SIGNALS
8002
CALIBRATION VALUE k[t][s] FOR RGB COMPUTED FROM READ VALUE OF COLOR PATCH AND STANDARD VALUE
8003
OBTAINED CALIBRATION VALUE FOR RGB SIGNALS STORED IN NON-VOLATILE RAM
8004
RET

FIG.31

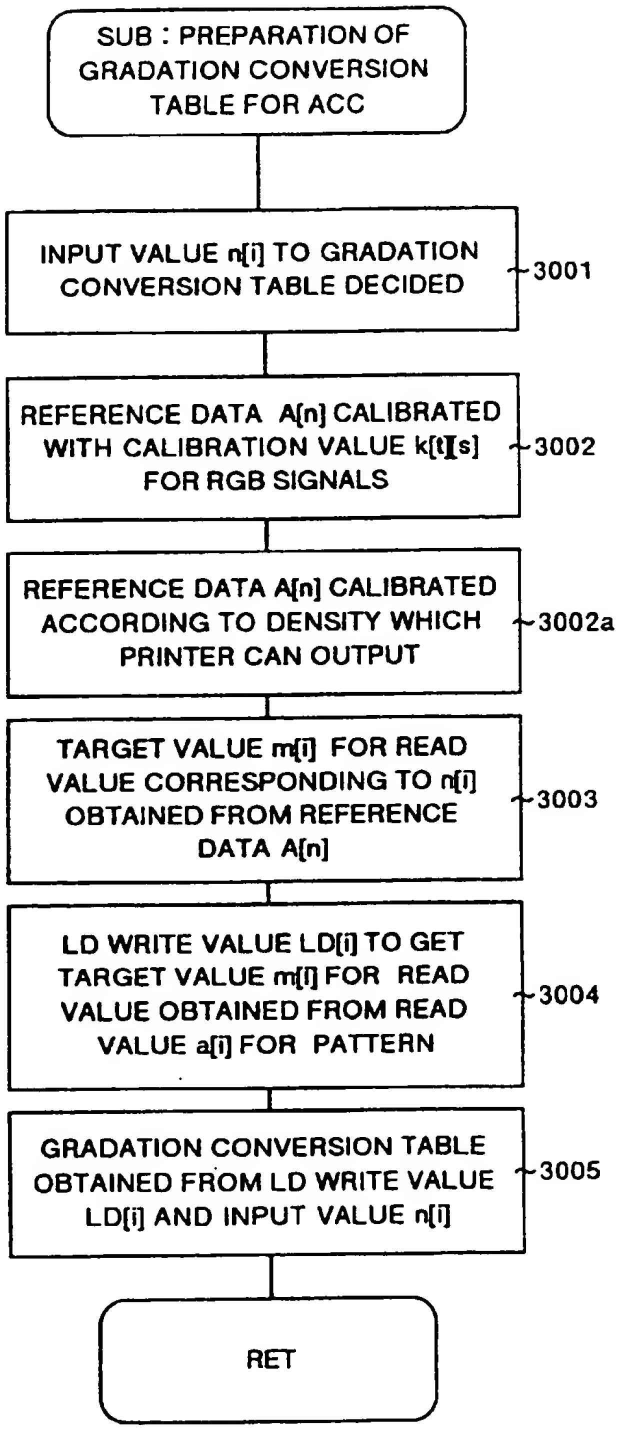

SUB : PREPARATION OF GRADATION CONVERSION TABLE FOR ACC
INPUT VALUE n[i] TO GRADATION CONVERSION TABLE DECIDED
3001
REFERENCE DATA A[n] CALIBRATED WITH CALIBRATION VALUE k[t][s] FOR RGB SIGNALS
3002
REFERENCE DATA A[n] CALIBRATED ACCORDING TO DENSITY WHICH PRINTER CAN OUTPUT
3002a
TARGET VALUE m[i] FOR READ VALUE CORRESPONDING TO n[i] OBTAINED FROM REFERENCE DATA A[n]
3003
LD WRITE VALUE LD[i] TO GET TARGET VALUE m[i] FOR READ VALUE OBTAINED FROM READ VALUE a[i] FOR PATTERN
3004
GRADATION CONVERSION TABLE OBTAINED FROM LD WRITE VALUE LD[i] AND INPUT VALUE n[i]
3005
RET

FIG.32
(PRIOR ART)

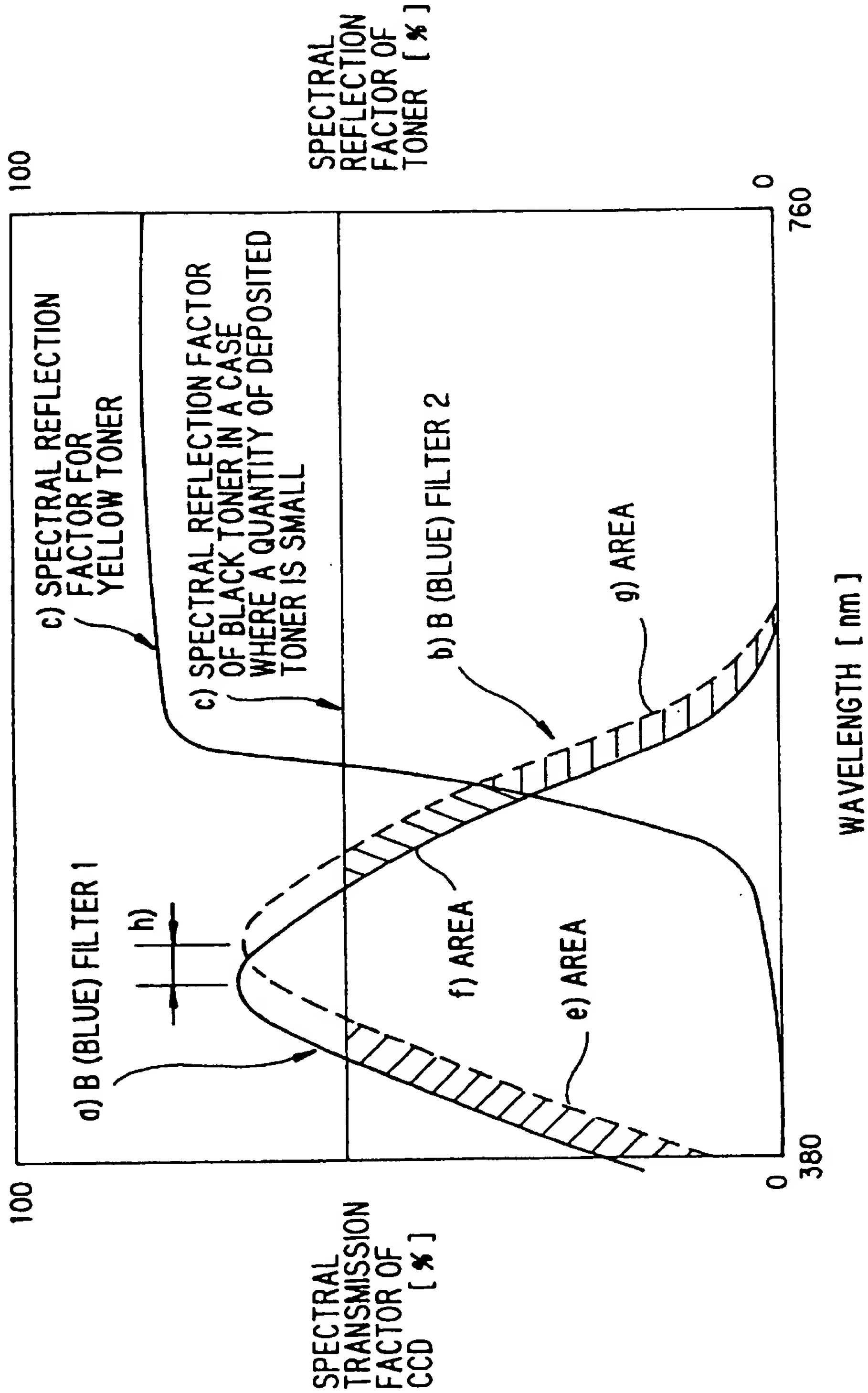


IMAGE FORMING APPARATUS

FIELD OF THE INVENTION

The present invention relates to an image forming apparatus such as a copying machine, a printer, and a facsimile machine each based on a digital system.

BACKGROUND OF THE INVENTION

Conventionally, in an image forming apparatus based on a digital system, an image signal conversion table (look up table: described as "LUT" hereinafter) has been used to correct output characteristics of an output device (an image forming means) such as a printer or to emphasize a particular density area. This image forming apparatus generally comprises an image reading means, an image processing means, an image writing means, and an image forming means, and the LUT described above is incorporated in the image processing means, converts an input image signal inputted from the image reading means into the image processing means and outputs the converted signal as an output image signal to the image writing means.

On the other hand, the LUT is made reflecting output characteristics for image density of an image forming means such as a printer, so that, in a case where output characteristics of the printer has changed because of degradation or contamination of the image forming means or the like, the LUT can not play a role for calibration.

To overcome the defect, as one of controls called process controls executed inside an image forming apparatus, a plurality of patterns each having different image density are formed on an image carrier such as a photosensitive body or a transfer body; the patterns are detected by an optical sensor by checking the reflected light or transmitted light to change charged potential, development bias, or an exposure to a laser beam according to a result of detection, or to correct a gradation calibration table for gradation conversion for image data.

This calibrating method provides the merits that it enables automatic calibration within an image forming apparatus and that intervention by an operator is not required, but because of the characteristics of the optical sensor, there is no change in the side of high density where a quantity of deposited toner is large, so that calibration is possible only in a range from low density to intermediate density where a quantity of deposited toner is small. Further it is impossible to correct a quantity of toner which fluctuates according to change in a transfer capability of a transfer section associated with passage of time or to correct fluctuation of image density caused by change in fixing capability of a fixing section.

In contrast, there has also been proposed a calibrating method in which a pattern image formed on an image carrier and transferred and fixed on a transfer member is read with a scanner and a gradation calibration table is selected or prepared according to the read data, or color conversion coefficients and an RGB-YMCK color conversion table are prepared. In this method, different from the calibrating method using an optical sensor as described above, intervention by an operator such as mounting a discharged transfer member onto a document base is required, but calibration of a high image density section where a quantity of deposited toner is large is possible, and there is provided the merit that change of image density due to change of fixing capability in the fixing section can be calibrated. As the calibrating method as described above, there has been known, for instance, the invention disclosed in Japanese Patent Laid-Open Publication No. HEI 5-114962.

On the other hand, in a scanner used in an image forming apparatus like a color copying machine, because of change during passage of time in spectral sensitivity of an RGB filter in a CCD (Charge Coupled Device) constituting the scanner or because of difference of spectral sensitivity in each image forming apparatus, even if the same color patch pattern or a gradation pattern is read, a value read by each scanner may vary from unit to unit. Description is made below for this phenomenon with reference to FIG. 32 showing non-uniformity of spectral transmission characteristic of a B (Blue) filter in a CCD.

In FIG. 32, a) indicates a spectral transmission factor of a B filter 1 in a CCD, b) indicates a spectral transmission factor of a B filter 2 in the CCD, c) indicates a spectral transmission factor of yellow (Y) toner, and d) indicates a spectral transmission factor of black (K) toner in a case where a quantity of deposited toner is small. The horizontal axis indicates a wavelength, while the vertical axis indicates a spectral transmission factor or a spectral reflection factor of the CCD. In this figure, a) and b) show an example of non-uniformity in a spectral transmission factor of the B filter. Herein it is assumed that the spectral transmission factors a) and b) have been shifted by a rate indicated at h) respectively, but the same consideration is applicable also to a case where the assumption as described above is not made.

Namely, comparing the light transmitted through the B filter 1 in a) to the light transmitted through the B filter 2 in b) under the spectral reflection factor d) of black toner in a case where a quantity of deposited toner is small, a quantity of light having transmitted through the filter B1 is larger by a quantity of light having transmitted through a region e), but is smaller by the light having transmitted through regions f) and g) as compared to a quantity of light having transmitted through the filter B2. Herein the spectral characteristics in a) and b) have been shifted by a rate in h) respectively, in a case of the light having transmitted through the B filter 1 in a), the quantity of light having transmitted through the region e) is equal to the quantity of light blocked by the regions f) and g), and for this reason a difference for a Blue signal between a) and b) is small as far as the black toner is concerned.

To strictly examine the different above, it is necessary to take into considerations the spectral characteristics of the light source and dependency of sensitivity of a CCD on wavelength, but when calibrating shading of a scanner, by using an achromatic-colored reflection plate with low dependency of a spectral reflection factor for instance in gray on wavelength in a visible light area, the difference between a) and b) is calibrated.

However, in a case of yellow (Y) toner, the difference between filters in a) and b) appears as a difference of light having transmitted through or having been blocked by the region g), and the difference is clearly larger than that in a case of black toner. Also the difference can not be calibrated even by a shading calibration using an achromatic-colored reflection plate. The non-uniformity in spectral transmission factors among filters in a CCD can be calibrated in a case of achromatic colors like white or gray by means of shading calibration so that the RGB data become uniform, but in a case of a document with a spectral characteristic dependent on wavelength, the calibration can not be executed appropriately, and sometimes values for R, G, and B may vary unit by unit.

The difference generates some influences when reading transfer paper with a gradation pattern of each color YMCK or color patch recorded thereon with a scanner and preparing

a gradation calibration table (γ-calibration table) to correct gradation characteristics of a printer section from the read values (this operation is called Auto Color Calibration, and is described as ACC hereinafter), and offset from an idealistic state causes this phenomenon. Also in a case where the spectral transmission characteristic changes due to change of performance of a scanner in a CCD during passage of time, or in a case where the spectral reflection characteristics of YMCK toner being used changes, an RGB ratio in read values for the YMCK toner changes. As described above, if calibration is performed, after change of an RGB ratio in values read by a scanner for the YMCK toner, with an RGB ratio before the change, offset from a correct value becomes rather larger.

SUMMARY OF THE INVENTION

It is a first object of the present invention to provide an image forming apparatus in which density of toner set after execution of ACC due to non-uniformity in spectral characteristics of a CCD in a scanner does not change for each apparatus and which can obtain good gradation by means of calibration.

It is a second object of the present invention to provide an image forming apparatus in which calibration can be carried out with an appropriate value even in a case where the spectral transmission characteristic changes due to change of performance of a CCD in a scanner during passage of time, or in a case where the spectral reflection character of used YMCK toner changes.

It is a third object of the present invention to provide an image forming apparatus in which a calibration value can easily be set.

It is a fourth object of the present invention to provide an image forming apparatus in which, by setting data for calibration of non-uniformity in spectral sensitivity among CCDs of discrete apparatuses with an external means, the non-uniformity can be calibrated by connecting this external means thereto.

It is a fifth object of the present invention to provide an image forming apparatus in which a calibration value can easily be set against change in spectral transmission characteristic of a CCD or in spectral reflection characteristic of YMCK toner.

An image forming apparatus according to the present invention comprises a scanner for optically scanning and reading a draft image, an image processing circuit for converting input image signals from this scanner to output image signals by referring to an image signal conversion table and outputting the converted signals, a laser optical system for writing image information on a photosensitive drum in response to the output image signals, developing units for forming images with toner, an image signal generating means for generating a plurality of gradation patterns, and a CPU which prepares and selectors an image signal conversion table according to read signals for gradation patterns read by the scanner; wherein a read signal for a gradation pattern comprises a plurality of signals with different spectral sensitivity respectively, and said image forming apparatus has a RAM to store calibration factors for the plurality of factors with different spectral sensitivity respectively and calibrates read signals according to a calibration factor from the RAM.

Other objects and features of this invention will become understood from the following description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing electric configuration of an image processing section according to Embodiment 1 of the present invention;

FIG. 2 is an organizational view showing an outline of a mechanism of the main body of a copying machine according to Embodiment 1;

FIG. 3 is a view for explanation of a control system of the main body of the copying machine shown in FIG. 2;

FIG. 4 is a block diagram showing a laser modulator according to Embodiment 1;

FIG. 5 is a flow chart for explanation of a sequence of preparing a gradation conversion table;

FIG. 6 is a view for explanation of selecting curvature for the entire section;

FIG. 7 is a view for explanation of the selected curvature;

FIG. 8 is a view showing an example of a conversion curve for changing gradation characteristics in a highlight area;

FIG. 9 is a flow chart showing operations for auto color calibration in an image density;

FIG. 10 is a plan view showing an operating section;

FIG. 11 is a plan view showing a liquid-crystal display screen of the operating section at the time of invoking an ACC menu;

FIG. 12 is a plan view showing a liquid-crystal display screen of the operating section when the performance of the auto color calibration required for using a printer is selected;

FIG. 13 is a plan view showing density gradation patterns on transfer paper when a print-start key is selected;

FIG. 14 is a plan view showing a liquid-crystal display screen of the operating section after the patterns are outputted onto the transfer paper;

FIG. 15 is a plan view showing a liquid-crystal display screen of the operating section during processing of auto color calibration;

FIG. 16 is a graph for explanation of calibration of a background color;

FIG. 17 is a flow chart showing a sequence of preparing a gradation conversion table when the ACC is performed;

FIG. 18 is a flow chart showing a sequence of selecting a gradation conversion table when the ACC is performed;

FIG. 19 is a plan view showing a liquid-crystal display screen of the operating section for displaying RGB calibration data;

FIG. 20 is a schematic view showing an example of configuration for setting and inputting calibration values for RGB signals;

FIG. 21 is a block diagram showing electric configuration of the view shown in FIG. 20;

FIG. 22 is a flow chart showing a sequence of preparation for setting and inputting calibration values for RGB signals;

FIG. 23 is a plan view showing an example of a color patch transferred onto transfer paper;

FIG. 24 is a block diagram showing another example for setting and inputting calibration values for RGB signals;

FIG. 25 is a flow chart showing a sequence of preparation for setting and inputting calibration values for RGB signals in FIG. 24;

FIG. 26 is a schematic view showing another further example for setting and inputting calibration values for RGB signals;

FIG. 27 is a block diagram showing electric configuration of the view shown in FIG. 26;

FIG. 28 is a block diagram showing electric configuration in a case where a toner patch is used in the configuration shown in FIG. 26;

FIG. 29 is a flow chart showing a sequence of preparation for setting and inputting calibration values for RGB signals in the configuration shown in FIG. 27 and FIG. 28;

FIG. 30 is a flow chart showing another further sequence of a case where calibration values for RGB signals are computed;

FIG. 31 is a flow chart showing a sequence of preparing a gradation conversion table when the ACC is performed; and

FIG. 32 is a graph showing dispersion of spectral transmission characteristics in a blue filter of a CCD based on the conventional technology.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Description is made hereinafter for embodiments, in which a case where the image forming apparatus according to the present invention is applied to an electronic photo copying machine (described simply as a copying machine hereinafter) is assumed as an example, with reference to the related drawings.

At first, description is made for a first embodiment of the present invention. FIG. 2 is a schematic view showing mechanical configuration of the main body of a copying machine according to the first embodiment.

In FIG. 2, successively arranged in the periphery of an organic photosensitive (OPC) drum **102** having a diameter of 120 mm as an image carrier provided in substantially the center of the main body of the copying machine **101** are an electrifying charger **103** for electrifying the surface of this photosensitive drum, a laser optical system **104** for irradiating the surface of the uniformly electrified photosensitive drum **102** with a semiconductor laser beam to form an electrostatic latent image, a black-developing device **105** for supplying toner for each color to the electrostatic latent image to be developed and obtaining each toner image in each color, three types of developing device **106, 107, 108** for yellow Y, magenta M, and cyan C, an intermediate transfer belt **109** for successively transferring the toner images in each of the colors formed on the photosensitive drum **102**, a bias roller **110** for applying a transfer voltage to this intermediate transfer belt **109**, a cleaning device **111** for removing toner residues on the surface of the photosensitive drum **102** after the toner image is transferred onto transfer paper, and a charge-removing section **112** for removing charge residues on the surface of the photosensitive drum **102** after the toner image is transferred thereonto. Provided therein are also a transfer bias roller **113** for applying a voltage for transferring the toner image transferred along the intermediate transfer belt **109** onto transfer paper and a belt cleaning device **114** for cleaning the image of toner residues on the intermediate transfer belt **109** after the toner image is transferred onto the transfer paper.

A fixing device **116** for fixing the toner image by being heated or pressured is provided in the exit side of an edge section of a transfer belt **115** for transferring transfer paper peeled from the intermediate transfer belt **109** after the toner image on the intermediate transfer belt **109** is transferred thereonto, and a paper feeder tray **117** is also attached to the exit section of this fixing device **116**.

A contact glass **118** as a document base arranged on the top section of the main body of a copying machine **101** and an exposing lamp **119** for irradiating a document on this contact glass **118** with scanning light are provided in the upper side of the laser optical system **104**, and a reflected light from the document is led to an image-formation lens **122** by a reflecting mirror **121** to be introduced into an image sensor array **123** of a CCD as a photoelectric transfer element. Image signals converted to electric signals in the image sensor array **123** of a CCD oscillate a semiconductor laser in the laser optical system **104** through the image processing apparatus not shown herein.

Next description is made for a control system of the copying machine with reference to FIG. 3. FIG. 3 is a view for explanation of the control system in the main body of the copying machine shown in FIG. 2.

As shown in FIG. 3, the control system has a main control section (CPU) **130**, and a ROM **131** and a RAM **132** to this main control section **130** are additionally provided therein. Connected to the main control section **130** are also a laser-optical system control section **134**, a power supply circuit **135**, an optical sensor **136**, a toner density sensor **137**, an environment sensor **138**, a photosensitive body surface potential sensor **139**, a toner supplying circuit **140**, an intermediate transfer belt driving section **141**, and an operating section **142** respectively through an interface I/O **133**. The laser system control section **134** adjusts laser output from the laser optical system **104**, and the power supply circuit **135** gives a specified discharging voltage for electrification to the electrifying charger **103**, gives a development bias at a specified voltage to the developing devices **105, 106, 107, 108**, and also gives a specified transfer voltage to the bias roller **110** as well as to the transfer bias roller **113**.

The optical sensor **136** comprises light-emitter such as light-emitting diodes or the like and light-receptors such as photosensors or the like each provided adjacent to an area of the image after being transferred from the photosensitive drum **102**, and a quantity of deposited toner in a toner image for a detection-pattern latent image formed on the photosensitive drum **102** and a quantity of deposited toner in the background color section are detected for each color respectively, and so-called potential residues on the photosensitive body after electrification thereon is removed is also detected.

The detection output signal from this photoelectric sensor **136** is applied to the photoelectric sensor control section not shown herein. The photoelectric sensor control section computes a ratio between the quantity of deposited toner in the detection-pattern toner image and the quantity of deposited toner in the background color section, compares the ratio value to the reference value to detect fluctuation in an image density, and corrects the control values for the toner density sensor **137**.

Further, the toner density sensor **137** detects a toner density according to changes of magnetic permeability in a developer existing in each of the developing devices **105** to **108**. The toner density sensor **137** has a function of applying a toner supply signal with amplitude, in a case where the detected toner density value is compared to the reference value and the toner density is found under the specified value which indicates a short of toner therein, corresponding to the shortage thereof to the toner supplying circuit **140**. The potential sensor **139** detects a surface potential of the photosensitive body **102** as an image carrier, and the intermediate transfer belt driving section **141** controls driving of the intermediate transfer belt **109**.

A developer containing M-toner and carrier is accommodated, for instance, in the magenta-developing device **107** and is agitated in association with rotation of a developer agitating member **202M**, so that the developer sucked up onto a sleeve **201M** by a developer restricting member is adjusted on the developing sleeve **201M**. This

supplied developer rotates in the direction of rotation of the developing sleeve 201M as a magnetic brush while it is magnetically carried on the developing sleeve 201M. Similarly, developing sleeves 201C, 201Y, and 201B are provided for C-toner, Y-toner, and B-toner, agitated by agitating member 202C, 202Y, and 202B, respectively, as shown in FIG. 2.

Next description is made for electric configuration of an image processing section with the reference to a block diagram shown in FIG. 1.

In FIG. 1, designated at the reference numeral 401 is a color scanner, at 402 a shading calibrating circuit, at 403 an RGB γ-calibrating circuit, at 404 an image separating circuit, at 405 an MTF calibrating circuit, at 406 a color conversion-UCR processing circuit, at 407 a scaling circuit, at 408 an image processing (creating) circuit, at 409 an MTF filter, at 410 a γ-calibrating circuit, at 411 a gradation processing circuit, and at 412 a printer.

A document to be copied is resolved into colors of R, G, B to be read by G, B to be read by the color scanner 401. Non-uniformity due to characteristics of an image pickup device or non-uniformity in irradiation of a light source or the like are calibrated in the shading calibrating circuit 402. Read signals from the color scanner 401 are converted from data for reflection factors to data for brightness in the RGB γ-calibrating circuit 403. Determination is made between a character section and a photographic section as well as between chromatic color and achromatic color in the image separating circuit 404. Degradation of an MTF characteristics in an input system, especially in a high frequency area is calibrated in the MTF calibrating circuit 405. The color conversion-UCR processing circuit 406 comprises a color calibration processing section for correcting a difference between color-resolution characteristics in the input system and spectral characteristics of color materials in an output system and computing a rate of color materials for YMC required for faithful color reproduction and a UCR processing for replacing a section in which three colors of YMC are superimposed on each other with Bk (black). The color calibration processing in the color calibration processing section can be realized by performing matrix-operation as described below.

Expression 1

$$\begin{bmatrix} Y \\ M \\ C \end{bmatrix} = \begin{bmatrix} a11 & a12 & a13 \\ a21 & a22 & a23 \\ a31 & a32 & a33 \end{bmatrix} \begin{bmatrix} B'' \\ G'' \\ R'' \end{bmatrix} \tag{1}$$

Herein, R", G", B" indicate complements of R, G, B respectively. Matrix factors a j i are decided depending on spectral characteristics of the input system and output system (color materials). Herein, an one-dimensional masking equation is used as an example, but by using a second term such as B"2, B" G", or further higher-term, color calibration can more precisely be executed. An operation expression may be changed according to a hue, or a Noigebauwer expression may be used. In any of the methods, Y, M, C can be obtained from values of B", G", R" (or may he B, G, R).

On the other, the UCR processing can be executed by computing using the below equations for each color.

$$Y' = Y - \alpha \cdot \min(Y, M, C) \tag{2}$$

$$M' = M - \alpha \cdot \min(Y, M, C) \tag{3}$$

$$C' = C - \alpha \cdot \min(Y, M, C) \tag{4}$$

$$Bk = \alpha \cdot \min(Y, M, C) \tag{5}$$

In these equations from (2) to (5), α indicates a factor for deciding a rate for UCR, and when α is equal to 1 (α=1), 100% of UCR processing is executed. This α may be a specified value, or in a high-density section, for instance, α is close to 1 and in the highlight section, an image in the highlight section can be smoothed by making α closer to 0.

A hue determining circuit 422 is connected to between the MTF calibrating circuit 405 and the color conversion-UCR processing circuit 406. Determination is made in this hue determining circuit 422 as to which hue signal among RGBCMY an RGB image signal indicates, and a color conversion coefficient is selected according to each hue.

In the scaling circuit 407, vertical and horizontal scaling is executed, and a repeat processing or the like is executed in the image processing (creating) circuit 408. Executed in the MTF filter 409 is processing for changing frequency characteristics of image signals such as edge enhancement or smoothing or the like according to a user's taste to an image such as a sharp image or a soft image or the like. Image signals are calibrated in the γ-calibrating circuit 410 according to characteristics of a printer 412. Processing such as eliminating a background color or the like can concurrently be executed also in the γ-calibrating circuit 410. Dither processing or pattern processing is executed in the gradation processing circuit 411.

Provided therein are interfaces I/F 413, 414 for processing image data read by the scanner 401 in an external image processing unit or the like or outputting the image data from the external image processing unit to the printer 412.

A CPU 415 for controlling the image processing circuit described above, a ROM 416, and a RAM 417 are connected to each other through a BUS 418. The CPU 415 is connected to a system controller 419 through a serial I/F, and commands from the operating section or the like not shown herein are sent thereto. It should be noted that, in FIG. 1, the reference numeral 421 indicates a pattern generating circuit, the reference numeral 422 indicates a hue determining circuit, and the reference numeral 423 indicates a selector although particular description is not made therefor herein.

Next description is made for a laser modulator with reference to the block diagram shown in FIG. 4. It is assumed herein that a write frequency is 18.6 MHz, and a scanning time for 1 pixel is 53.8 nsec. 8 bits of image data can be γ-converted with a look up table (LUT) 451. The 8 bits of image data are converted to a 8-value pulse width according to signals with the 3 bits at the highest end of the 8 bits of image signal by a pulse width modulator (PWM) 452, are subjected to 32-value power modulation according to signals with the 5 bits at the lowest end by a power modulator (PM) 453, and laser diodes (LD) 454 emit light according to the modulated signals. Light-emitting amplitude is monitored by a photodetector (PD) 455 to be calibrated each one dot.

It should be noted that the maximum value by a laser beam amplitude can be changed to 8 bits (256 levels) discretely from image signals. A beam diameter (this beam diameter is specified as a width when the beam amplitude is attenuated to 1/e2 while the beam amplitude at rest is the maximum value) in the main scanning direction to a size of one pixel is not more than 90%, and desirably 80%. In conditions of 400 DPI and 63.5 μm per one pixel, a desirable beam diameter is not more than 50 μm.

Description is made for a sequence of preparing a gradation conversion table (LUT) in the γ-calibrating circuit 410 with reference to the flow chart shown in FIG. 5. In this sequence, at first, curvature for the entire section is selected (step 1001), and then curvature for the low image density

(highlight) section and that for the high image density (shadow) section are selected (steps **1002**, **1003**). Then, the curvature for the entire section is multiplied by a factor IDMAX so that the image density has a desired value to prepare a gradation conversion curve (step **1004**).

Detailed description is made for the processing in the step **1001** with reference to FIG. **6**. FIG. **6** is a view for explanation of an operation for selecting curvature for the entire section. It is assumed herein that a gradation curve as a reference is A, gradation conversion for changing curvature for the entire section is B, gradation conversion for changing curvature for the highlight area (low density area) is CH, and gradation conversion for changing curvature for the shadow area (high density area) is CS. Then, assuming that the gradation curve obtained as a result of gradation conversion of the gradation curve A according to the gradation conversion B is E, and this result is described by the following expression of E=B and as (A).

Outline of the above expression can more specifically be described as follows using the format of a programming language C:

Expression 2

```
                    <List 1>
typedef int Table[256];
Table          A, E;
int    B( int A, in curvature)
{
       int    value;
       /*   Computing for changing curvature    */
       according to a degree of curvature
       . . .
       return    value;
}
       Processing for changing
/* full() : curvature for the entire section */
Table    full(int curvature)
{
       /* curvature is a degree of curve    */
       int    i;
       for(i = 0; i < = 255; i+ +)
              E[i] = B( A[i],    curvature);
       return    E;
}
```

Herein, B indicates a function for changing the curvature of A.

As an example of this function, in a case of 8-bit image signals, it is possible to use a quadratic Pege function satisfying the following conditions of 0=B (0, n), 255=B (255, n) (n: an arbitrary integer).

The Pege function satisfying the above conditions is described as a quadratic Pege curve from a straight line P0P1 connecting a starting point P0 (0, 0) to an endpoint P1 (255, 255) as shown in FIG. 7, a straight line L intersecting this straight line P0P1, and a control point P3 existing on this straight line L and setting a distance d from a point of the intersection of the straight line P0P1 and the straight line L to a parameter.

In the function described above, by proportioning a distance d thereto according to an integer curvature which is an argument of the function B, the curvature can be changed. Description is made for a case of a function for the straight line L1 intersecting at right angles the straight line P0P1 and for a case of a function for straight lines L2 parallel to the vertical axis of the figure as examples.

As for a control point in the first example, when a distance d to this point is set to a parameter to a central point Pc, of a line segment P0P1 made of both edge points P0, P1, which is Pc=(P0+P1)/2=(127.5, 127.5), (127, 127), or (128, 128), the control point P3 is obtained by the following expression:

$$\begin{aligned} P3(d) &= Pc + \left(-d/\sqrt{2},\ d/\sqrt{2}\right) \\ &= \left(127.5 - d/\sqrt{2},\ 127.5 + d/\sqrt{2}\right) \end{aligned} \tag{6}$$

With this expression, a gradation conversion curve P (d, t) can be obtained by the following expression:

$$P(d,\ t) = P0 \cdot t^3 + 2P2(d)t(1-t) + P1(1-t)^3 \tag{7}$$

However, t is a parameter in a range of 0≦t≦1. P (d, t) is given as a set (x, y) of input (x) and output (y) to the gradation conversion curve, so that, assuming that x=A from the integer A given as an argument to the function B ( ), t is obtained from the expression (7), and the obtained t is substituted into the expression (7) again to obtain an output value y.

Actually, in place of computing as described above each time, all the sets (0≦x≦255) are previously obtained, and by storing the values as a table in the ROM **416**, a time required for computing can be reduced. Several sets (or some tens of sets) of this gradation calibration table are stored in the ROM **416** by changing the curvature thereof. A curvature is given by an argument curvature to the function B ( ).

With this feature, <List 1> is rewritten as follows:

Expression 3

```
const      table_max = 9:
typedef int    Table[256];
Table      A, E, B[table_max = 9;
     Processing for changing
/*(): curvature of the entire sectian
Table    full(int curvature)
{
        curvature specifies a degree
       /* of curve.        */
       int    i;
       for (i = 0; i < = 255; i+ +)
            E[i] = B[curvature][ A[i] ];
       return      E;
}
main()
{
        /* curvature is a degree of curve      */
        int       curvature = 1;
        E = full( curvature);
}
```

It should be noted that, in the example described above, Table_max=9 is assumed, so that the table includes 9 lines each having a different curvature respectively. Also, in the example as described above, the Pege curve is used, however, in addition, a higher function or an index/a logarithmic function or the like can be used as required.

Also in the processing in step **1002** and **1003**, curvature for the low image density (highlight) area and a high image density (shadow) area can be changed by executing processing like that in step **1000**. So the <List 1> can be rewritten to a more general form, as follows.

Expression 4

<List 3>

```
const      table_max = 9;
typedef int Table[256];
Table      A, E, B[table_max];
        Processing for changing
/* Transform(): curvature                  */
Table   Transform(Table Transformer, Table Original)
{
/*      This function executes curvature of the           *
*       gradatian conversion curve called Original        *
        using the gradation conversion curve
*                                       called Transformer */
        int    i;
        for(i = 0;i < = 255;i+ +)
                E[i] = Transformer[ Original[i] ];
        return E;
}
main()
{
        /* curvature is a degree of curve      */
        int    curvature = 1;
        E = Transform( B[curvature], A);
        Curvature of gradation conversion curve A is
/*      changed using the gradation conversion curve B*
*       [curvature]      */
}
```

When conversion of a highlight conversion curve CH (h) as well as of a shadow conversion curve CS (s) is executed, the expression can be described as follows:
Expression 5

<List 4>

```
const      table_max =9;
typedef int    Table[2569 ;
Table      A, B[table_max], E, CH[table_max], CS[table_max];
           Processing for
/* Transform(): changing curvature         */
Table    Transform( Table Transformer, Table Original);
main()
{
           int       curvature, h, s;
/*         Curvature of a curve is changed by changing numerical values
           of curvature, h, s   */
           /* Curvature of the entire section is changed */
           E = Tranform( B[curvature, A):
             Curvature of the low image density
           /*(highlight) section is changed          */
           E = Tranform( CH[h], E):
             Curvature of high image density
           /* (shadowed) section is changed          */
           E = Tranform( CS[s], E):
}
```

In this expression, curvature, h, s indicate values for deciding curvatures for the entire section, highlight section, and shadow section. It should be noted that curvatures for the highlight section and for the shadow section are prepared independently from each other.

A gradation conversion curve for changing curvature for a particular density area like in a highlight area and a shadow area is generated as described below.

Namely, a gradation conversion curve is generated using a tertiary Pege curve from a straight line **P0P1** between a starting point **P0** and an endpoint P1, a straight line L intersecting at right angles this straight line **P0P1**, and a control point P2 existing on this straight line L and setting a distance d from a point of the intersection of the straight line **P0P1** and the straight line L to a parameter.

Also in this case, description is made for a case where conversion is made by using a function for the straight line L1 intersecting at right angles the straight line **P0P1** and for a case where conversion is made by using a function for a straight lines L2 (not shown herein) parallel to the vertical axis in the figure like in the case where conversion is made by using the quadratic Pege curve.

A conversion curve for changing gradation characteristics for a highlight area is generated, for instance, as follows, as shown in FIG. **8**. It is assumed that a starting point **P0** and an endpoint P1 are set as follows: P0=(0, 0) and P1=(255, 255), respectively, and that a first control point P2 is set to P2=(32, 32). The control point P3 in the example shown in FIG. **7** is obtained as follows by setting a distance d from the point of intersection of the straight line **P0P1** and the straight line L1 as a parameter:

$$P3(d)=(16, 16)+(-d/\sqrt{2}, d/\sqrt{2})$$

Also, the control point P3 in the second example is obtained as follows by setting a distance d from the point of intersection of the straight line **P0P1** and the straight line L1 as a parameter:

$$P3\ (d)=(16, 16)+(0, d)$$

By using these values from **P0** to P3, a gradation conversion curve P (d, t) is obtained through the following expression:
Expression 6

$$P(d, t)=P0\cdot t^3+3\cdot P2\cdot t^2\cdot(1-t)+3\cdot P3(d)\cdot t\cdot(1-t)^2+P1\cdot(1-t)^3 \qquad (8)$$

Herein, P1=(255, 255) is set as an endpoint, but it is assumed that an endpoint P1 is set to a point on a line segment m: (0, 0)-(255, 255) such as P1=(64, 64) or the like. In this case, a line segment not included in the line segment **P0P1** on the line segment m is used as equivalence conversion for gradation conversion as it is, and areas other than the line segment function as a gradation conversion curve for changing curvature for particular density area like the highlight area as well as the shadow area.

Next description is made for operations of auto color calibration (ACC) for an image density (gradation) with reference to FIG. **9** to FIG. **15**.

FIG. **9** is a flow chart showing operations for auto color calibration in an image density, FIG. **10** is a plan view showing an operating section, FIG. **11** is a plan view showing a liquid-crystal display screen of the operating section at the time of invoking an ACC menu, FIG. **12** is a plan view showing a liquid-crystal display screen of the operating section when the performance of the auto color calibration required for using a printer is selected, FIG. **13** is a plan view showing density gradation patterns on transfer paper when a print-start key is selected, FIG. **14** is a plan view showing a liquid-crystal display screen of the operating section after the patterns are outputted onto the transfer paper, and FIG. **15** is a plan view showing a liquid-crystal display screen of the operating section during processing for auto color calibration.

Provided in the upper side of the main body of a copying machine are a plurality of operating buttons **304**, as shown in FIG. **10**, for executing various type of operations such as preparatory heating/mode clear, memory call, interrupt operation, color adjustment/registration, program, option, and area processing or the like together with a start button **301**, a clear/stop button **302**, a ten key **303** for setting the number of sheets to be copied or the like each in the front side of the contact glass **118**. A display screen **305** of a liquid-crystal display unit (described also as a liquid-crystal

screen hereinafter) is also provided thereon so that it is surrounded by these buttons. The display screen 305 has a tablet function for outputting a signal by pressing a display point or contacting a display point.

When an ACC menu is called on the liquid-crystal screen 305 of the operating section 142 as shown in FIG. 10, the liquid-crystal screen 305 is switched from the display thereon to the display as shown in FIG. 11. When [Execute] of the auto color calibration for "copying is used" or "printing is used" is selected, the display on the liquid-crystal screen 305 is changed to the display as shown in FIG. 12. In a case where "copying is used" is selected, the gradation calibration table used when a copier is used is changed, and in a case where "printing is used" is selected, the gradation calibration table used when a printer is used is changed each according to reference data.

Herein, when "print start" is selected on the display screen 305 shown in FIG. 12, as shown in FIG. 13, a plurality of density gradation patterns 311 corresponding to each of image quality modes for colors of YMCK, characters and photographs are formed on transfer paper 310 (step 2001 in FIG. 9). It should be noted that the reference numeral 312 indicates a position specifying mark. The density gradation patterns are previously stored and set in the ROM of the computer 420 shown in FIG. 1. A written value for a pattern has 16 patterns such as 00h, 11h, 22h, . . . EEh, FFh displayed in hexadecimal digit. In FIG. 13, a patch for gradation except a background color section is displayed, and an arbitrary value, of 8 bits of signal in 00h to FFh, can be selected. In the character mode, dither processing such as pattern processing is not executed, but a pattern is formed in 256 levels per one dot, while in a photograph mode, a written value for a laser is formed by distributing a sum of write values by two pixels each adjacent to each other in the main scanning direction.

Namely, processing of patterns in a case where a written value for a first pixel is n1 and a written value for a second pixel is n2 are distributed as follows:

In a case of $n1+n2 \leq 255$,

a written value for the first pixel: $n1+n2$

a written value for the second pixel: 0

In a case of $n1+n2>255$,

a written value for the first pixel: 255

a written value for the second pixel: $n1+n2-255$ or,

In a case of $n1+n2 \leq 128$,

a written value for the first pixel: $n1+n2$

a written value for the second pixel: 0

In a case of $128<n1+n2 \leq 256$,

a written value for the first pixel: 128

a written value for the second pixel: $n1+n2-128$

In a case of $256<n1+n2 \leq 383$,

a written value for the first pixel: $n1+n2-128$

a written value for the second pixel: 128

In a case of $383<n1+n2$,

a written value for the first pixel: 255

a written value for the second pixel: $n1+n2-255$

Pattern processing used for actual image forming is used other than the above processing.

After a pattern 311 is outputted onto transfer paper 310, a display on the display screen 305 is changed to a display as shown in FIG. 14 so that the transfer paper 310 is mounted on the contact glass 118.

The transfer paper 310 with the pattern 311 formed thereon is placed on the contact glass 118 (step 2002 in FIG. 9), and "read start" is selected on the display screen 305 as shown in FIG. 14, then the scanner 401 runs, and RGB data for a YMCK density pattern 311 is read (step 2003 in FIG. 9). In this processing, data for the pattern section and data for a background color section of the transfer paper 310 are read.

The read value for the pattern 311 is calibrated using a RGB calibration value described in detail later (step 2004 in FIG. 9). In a case where processing is executed using data for a background color (step 2005 in FIG. 9), processing for background color data to read data is executed (step 2006 in FIG. 9), and in a case where the reference data is calibrated (step 2007 in FIG. 9), a YMCK gradation calibration table is prepared and selected (step 2009 in FIG. 9) after processing (step 2008 in FIG. 9) for a high-image density section to the reference data is executed.

The processing is executed in each of the image quality modes such as for each color of YMCK (step 2010 in FIG. 9), and for photographs and characters (step 2011 in FIG. 9). During the processing, the display on the display screen 305 is changed to that as shown in FIG. 15. A key for [return to the original value] is shown on the display screen 305 as shown in FIG. 11 so that, in a case where the operator gets an undesirable result of image forming with the YMCK gradation calibration table after the processing thereof is finished, the operator can select the YMCK gradation calibration table before processing thereof is executed.

Next description is made for calibration of a background color.

There are two objects for calibration processing of a background color. One of them is to correct a whiteness degree of transfer paper used for ACC, and the other one is to correct color or the like of something on a rear surface of the transfer paper or seen through the paper. Namely, the former is executed to eliminate the difference between whiteness degrees of used transfer paper because, even if images are formed at the same time in the same types of apparatus, values read by the scanner 401 are different from each other. As a demerit generated when a whiteness degree is not calibrated, there is a case where a desired color reproduction can not be obtained because, if regenerated paper having a low whiteness degree is used for the ACC, and when a yellow gradation calibration table is prepared, calibration is executed so that a yellow element therein is reduced because regenerated paper generally contains a lot of yellow element, and in a case where an image is copied onto art paper having a high whiteness degree with the calibration in the above state, an obtained image results in containing not much yellow element therein.

The former is executed to eliminate a case where color of a pressure plate for pressing down transfer paper or the like is seen through the paper to be disadvantageously read by the scanner 401 and copied when the transfer paper used for the ACC is not thick enough in its thickness (paper thickness). For instance, in a case where an auto document feeder called as ADF is mounted in place of a pressure plate, a belt is used for carrying a document, paper has a low whiteness degree and sometimes has slightly grayish white because of a rubber based material used for this belt. In a case where the paper having the color described above is used, an image signal to be read is read as a signal for an image over which the density is apparently higher than original one, so that, when a YMCK gradation calibration table for the image is prepared, the density therefor is intentionally made lower by the degree to be the original one. In a case where thick paper having low permeability is used this time in the above state, the image is reproduced as one in a low density on the whole, so that a desirable image can not always be obtained.

To prevent the inconvenience as described above, a image signal read from the pattern section is calibrated according to an image signal from the background color section of the paper.

However, there are some merits even in a case where the calibration as described above is not executed. Namely, in a case where transfer paper always containing a lot of yellow element as regenerated paper, the paper to which any calibration is not executed has better color reproduction to color with a yellow element. In a case where only thin transfer paper is used, there is the merit that a gradation calibration table matched to thin paper can be prepared.

As described above, and as shown in FIG. **11**, keys for calibrating or not calibrating a background color are displayed on the display screen **305** so that the calibration of the background color can be ON or OFF according to the user's conditions and taste.

It is assumed that a written value for a gradation pattern formed on a photosensitive body is set to LD (i) (wherein i=0, 1, . . . 9), and a vector of read values for the formed pattern by the scanner **401** is set to v[t][i](r[t][i], g[t][i], b[t][i]) (t=Y, M, C, or K, i=0, 1, . . . 9). It should be noted that, in place of (r, g, b), a gradation pattern may be described by brightness, chroma, hue angle (L^*, c^*, h^*), or brightness, redness, blueness (L^*, a^*, b^*) or the like. It is also assumed that read values for white color as reference values previously stored in the ROM **416** or RAM **417** are set to values (r[W], g[W], b[W]).

When it is assumed that a pattern number of a density in an image is set to the k-th pattern (for instance, a pattern or the like of which image density is highest is selected) read values for a pattern (Δr[t][k], Δg[t][k], Δb[t][k]) is obtained as follows from read values (r[t][i], g[t][i], b[t][i]) for RGB signals to each of YMCK toner:

Expression 7

$$\Delta r[t][k]=r[W]-r[t][k]$$

$$\Delta g[t][k]=g[W]-g[t][k]$$

$$\Delta b[t][k]=b[W]-b[t][k] \tag{9}$$

On the other hand, in the RAM **417**, percentages of RGB elements in the read value for a pattern is stored for each of the YMCK toners as follows:

Expression 8

$$k[s][t](s=R, G, \text{ or } B;\ t=Y, M, C, \text{ or } K)\{k[s][t]1\} \tag{10}$$

{k[s][t]1} in expression (10) indicates that a decimal close to a numeral 1 is taken, but inside a copying machine, it is held as integer data as described below:

Expression 9

$$k[s][t]=k1[s][t]/2^n (k1[s][t] \text{ is an integer of } 2^n)$$

The data is, for instance, n=10, 2^n=1024 or the like. The values for K[s][t] which are calibration values for RGB signals obtained as described above are shown in Table 1.

TABLE 1

	Calibration values for RGB signals:k [s] [t]		
	s		
t	R	G	B
K	1.00	1.00	1.00
C	1.05	1.00	0.95

TABLE 1-continued

	Calibration values for RGB signals:k [s] [t]		
	s		
t	R	G	B
M	1.00	1.00	1.00
Y	1.00	1.00	0.95

Calibration data for the RGB signals shown in Table 1 is displayed, as shown in FIG. **19**, on the display screen **305** of the operating section in the main body of the copying machine **101**, and those numerical values can be inputted by pressing down with a finger the corresponding section in the display area. Inputted data is stored in the RAM **417**.

By using the values in the expressions (9), (10), the values v[t][i](r[t][i], g[t][i], b[t][i]) (t=Y, M, C, or K, i=0, 1, . . . 9) read by the scanner **401** are calibrated as follows. Herein, description is made for a case of t=C (Cyan). RGB elements in the read values for cyan toner are calibrated as follows:

Expression 10

$$r1[C][i]=r[C][0]-\Delta r[t][k]\times k[r][t]$$

$$g1[C][i]=g[C][0]-\Delta g[t][k]\times k[g][t]$$

$$b1[C][i]=b[C][0]-\Delta b[t][k]\times k[b][t]$$

and, the calibrated values are set to new values (r[t][i], g[t][i], b[t][i]), and are used as follows.

Next description is made for a method of generating a gradation conversion table (LUT) executed in the γ calibrating circuit **410** as a γ conversion processing section when ACC is executed.

In the read values for a pattern v[t][i](r[t][i], g[t][i], b[t][i]), image signals for each complementary color of YMC toner are b[t][i], g[t][i], r[t][i]respectively, so that only image signals for complementary colors are used. Herein, to make the description below simple, a[t][i](i=0, 1, . . . 9; t=C, M, Y, or K) is used to be shown. A gradation conversion table is prepared, which makes the processing simple. It should be noted that, even if any image signal of RGB is used, sufficient precision can be obtained as far as black toner is concerned, however, a G (green) element is used.

The reference data is given by a set of values **v0**[t][i](**r0** [t][i], **g0**[t][i], **b0**[t][i]) read by the scanner **401** and the corresponding write values LD[i](i=1, 2, . . . 10) by a laser. Similarly, to make the description below simple, by using only complementary color image signals for YMC, the following expression is described:

Expression 11

$$A[t][n[i]](0\leqq n[i]\leqq 255,\ i=1, 2, \ldots, 10,\ t=Y, M, C, \text{ or } K)$$

A YMCK gradation conversion table can be obtained by comparing the a[LD] described above to the reference data A[n] stored in the ROM **416**. Herein, n indicates an input value to the YMCK gradation conversion table, and the reference data A[n] indicates a target value for a read image signal that the YMC toner pattern outputted at a laser write value LD[i] after the input value [n] is subjected to YMCK gradation conversion is read by a scanner. It should be noted that the reference data A[n] has two type of reference data, one of which is one for executing calibration according to an image density enabling output by a printer, and the other of which is one for not executing calibration. Determination is made as to whether calibration is executed or not according

to the data for determination, described later, previously stored in the ROM **416** or the RAM **417**. This calibration is described later.

By obtaining LD corresponding to A[n] from the a[LD] described above, laser output values LD[n] corresponding to input values n to a YMCK gradation conversion table is computed. By computing laser output values with input values i=0, 1, 2, . . . 255 (when it is 8 bits of signal), a gradation conversion table can be obtained.

When it is operated, in place of the above processing to all the input values n=00h, 01h, . . . FFh (hexadecimal) to the YMCK gradation conversion table, the processing is executed only to some of the values like n[i]=0, 11h, 22h, . . . FFh by skipping some therebetween, and for values other than the above values, interpolation is executed by using a spline function or the like, or a table closest to the sets of (0, LD[0], [11h, LD[11h]]), (22h, LD[22h]]), . . . , (FFh, LD[FFh]]) each obtained by the above processing among the YMCK γ-calibration tables previously stored in the ROM **16** is selected.

Description is made for the above processing with reference to the graph shown in FIG. **16**. FIG. **16** is a graph for explanation of calibration of a background color. The X-axis in the upper right quadrant (a) of FIG. **16** indicates an input value n to the YMCMK gradation conversion table and the Y-axis therein indicates a value (after the processing) read by the scanner **401**, which indicates the reference data A[1] described above. The value (after the processing) read by the scanner **401** is a value, in contrast to a value obtained by reading a gradation pattern by the scanner **401**, obtained by RGB γ-converting (conversion is not executed here), averaging and adding the read data in some points of the gradation pattern, and the obtained value is processed herein as 12 bits of data to improve operational precision. The X-axis in the upper left quadrant (b) thereof indicates a value (after the processing) read by the scanner **401** like in the Y-axis. The Y-axis in the lower left quadrant (c) indicates a written value by a laser beam (LD). This data a[LD] indicates characteristics of a printer. The write value by a laser beam (LD) for actually formed pattern includes 16 values in total such as 00h (a background color), 11h, 22h, . . . , EEh, FFh, which indicate values by skipping therebetween, however, values not detected between the detected points are interpolated herein, so that the graph is regarded as a continuous graph. The graph in the lower right quadrant (d) thereof indicates a YMCK gradation conversion table LD[1] which is an object to be obtained.

Values of the X-axis and Y-axis of the graph (f) are the same as those in the graph (d). In a case where a gradation pattern for detection is formed, the YMCK gradation conversion table (g) shown in the graph (f) is used. The X-axis of the last graph (e) is the same as that in the lower left quadrant (c), which indicates linear conversion for the convenience to show a relation between the write values of LD when a gradation patter is prepared and values read by the scanner **401** (after the processing). The reference data A[n] corresponding to an input value n is obtained from the graph shown in FIG. **16**, and LD output LD[n] to obtain A[n] is obtained along the arrow (1) in the figure using the read value a[LD] for the gradation pattern.

Next description is made for a sequence of operation with reference to FIG. **17**. FIG. **17** is a flowchart showing a sequence of preparing a gradation conversion table when the ACC is executed.

At first, input values required for obtaining a YMCK γ-calibration table are computed (step **3001**). Herein, it is assumed that n[1] is set to the following values: n[i]=11 [h] xi (i=0, 1, . . . , imax=15). Then, the reference data A[n] is calibrated according to an image density in which an image can be outputted onto a printer **412** (step **3002**). Herein, it is assumed that read values by a laser in which the maximum image density enabling preparation by the printer **412** can be obtained is set to FFh (indicated by hexadecimal) and the read value m[FFh]for a pattern at this time is set to mmax. It is assumed that the reference data A[i](i=0, 1, . . . , i1) is one with which calibration is not executed over the area from the side of a low image density to the side of an intermediate image density, the reference data A[i](i=i2+1, . . . , i max) (i2≧i1, i2≦i max−1) is one with which calibration is not executed in the side of a high image density, and the reference data A[i](i=i1+1, . . . , i2) is one with which calibration is executed therein.

In an example described below. Description is made for concrete method of computing assuming that a signal is an image signal to which RGB γ-conversion is not executed and which is proportional alto a reflection factor of a document. Of the reference data with which calibration is not executed, a difference Δref between the data is computed from the reference data A[i2+1] with the lowest image density in a high image density section as well as from the reference data A[i1] with the lowest image density in a low image density section.

Namely, it is assumed as follows:

$$\Delta ref=A[i1]-A[i2+1] \tag{11}$$

On the other hand, in a case of a reflection factor linear or a brightness linear in which RGB γ-conversion as reverse processing is not executed, Δref is larger than 0 (Δref>0). Similarly, a difference Δdet is computed from the read value mmax for a pattern with which the maximum image density enabling preparation by the printer **412** can be obtained. Namely, it is assumed as follows:

$$\Delta det=A[i1]-mmax \tag{12}$$

From the expressions (11) and (12), it is assumed that the reference data A[i](i=i1+1, . . . , i2) with which calibration is executed in a high density section is set to that as follows:

$$A[i]=A[i1]+(A[i]-A[i1])\times(\Delta det/\Delta ref)\quad (i=i1+1, i1+2, \ldots, i2-1, i2) \tag{13}$$

Then, the read image signal m[i] by the scanner **401** corresponding to the n[i] obtained in step **3001** is obtained from the reference data A[n] (step **3003**). Actually, the reference data, corresponding to values n[i] indicating not all the values to be detected, A[n[j]] (0≦n[j]265, j=0, 1, . . . , j max, n[j]≦n[k] for j≦k) is made as follows. Namely, j [0≦j≦j max] to be n[j]≦n[i]<n[j+1] is computed.

In a case of 8 bits of image signal, if the reference data is previously obtained as n [0]=0, n[j max]=255, n[j max+1]=n[j max]+1, A[j max+1]=A[j max], the computation becomes easier.

As far as a space in the reference data is concerned, a space of n[j] as small as possible is better because high precision of the γ-calibration table finally obtained can be achieved.

A value m[i] is obtained from the following expression using the value j computed as described above:

$$m[i]=A[j]+(A[j+1])-A[i])\cdot(n[i]-n[j])/(n[j+1]-n[j]) \tag{14}$$

Herein, values are interpolated with a linear expression, however, interpolation may be executed thereto with a higher function or a spline function or the like. In that case, m[i] is obtained as follows:

$$m[i]=f(n[i])$$

Also, in a case of a k-th function, an expression is made as follows:

Expression 17

$$f(x)=\sum_{i=0}^{k} b_i x_i$$

Then, write values LD[i] by LD to obtain m[i] computed in step **3003** is obtained according to the same sequence as that in step **3003** (step **3004**).

Namely, in a case where image signal data which is not subjected to RGB γ-conversion is processed, a value of a[LD] is smaller as a value of LD is larger. Namely, the expression is as follows:

In contrast to LD[k]<LD[k+1],

$$a[LD[k]]\geqq a[LD[k+1]]$$

Herein, it is assumed that values when a pattern is formed are set to 10 values such as LD[k]=00h, 11h, 22h, . . . , 66h, 88h, AAh, FFh, (k=0, 1, . . . , 9). That is because spaces between write values LD [k] for a pattern are narrow since fluctuation of read values by the scanner **401** to a quantity of deposited toner is large in an image density with small quantity of deposited toner, and because spaces therebetween are widened for reading since fluctuation of read values by the scanner **401** to a quantity of deposited toner is small in an image density with large quantity of deposited toner.

As some merits provided by the above processing, a pattern is formed with the write values by LD as described above because consumption of toner can be reduced as compared to a case where the number of patterns is increased such as LD[k]=00h, 11h, 22h, . . . , EEh, FFh (16 in total) or the like, fluctuation to write values by LD is small in a high image density area, and a narrow space between write values by LD is not always effective to improve the precision thereof because read values are easily reversed due to influence of a non-uniform potential on the photosensitive body, non-uniform deposited toner thereon, and a non-uniform potential on toner or the like thereover.

Herein, the following expression is obtained:

To LD[k] satisfying the condition of

$$a[LD[k+1]]\geqq m[i]>a[LD[k+1]]\ \ LD[i]=LD[k]+(LD[k+1]-LD[k])\cdot(m[i]-a[LD[k]])/(a[LD[k+1]]-a[LD[k]])$$

When the expression is set to 0≦k≦k max [k max>0], and in a case of a[LD[k max]]>m[i] (in a case of a high image density in the target value obtained from the reference data),

$$LD[i]=LD[k]+(LD[k\max]-LD[k\max-1])\cdot(m[i]-a[LD[k\max-1]])/(a[LD[k\max]]-a[LD[k\mathrm{mas}-1]])$$

the above expression is made, and a pattern is estimated by extrapolation with a linear expression.

With this processing, a set [n[i], LD[i]] (i=0, 1, . . . , 15) of input values n[i] to a YMCK γ-calibration table and output values LD[i] is obtained.

Then, based on the obtained values [n[i], LD[i]] (i=0, 1, . . . , 15), interpolation is executed with a spline function, or the γ-calibration table stored in the ROM **416** is selected (step **3005**).

Next, a method of selecting a γ-calibration table is described in relation to preparation of the calibrated gradation curve described above with reference to FIG. **18**. FIG. **18** is a flowchart showing a sequence for selecting a gradation conversion table during execution of ACC.

At first, coefficient IDMAX [%] applied to the entire γ-calibration table (step **S4001**) is computed. Herein in a case of n [imax]=FFh, IDMAX is set to LD[imax]/FFh×100 [%]. Also herein an output value LD[i] to the YMCK γ-calibration table is rewritten assuming LD'[i]=LD[i]×100/IDMAX. With the operations, there is no necessity to take into considerations the IDMAX in selection of a γ-calibration table.

Then curvature h, and s, which are indices for curved section of the whole section, highlight section, and shadowed section respectively, are selected. For that purpose, at first, the curvature m for the whole section is selected (step **S4002**). Basically m is selected so that a sum of square of errors between the finally obtained gradation conversion curve E[j] (0≦j≦255) and a set (n[i], LD[i]) (0≦i≦15) of the input value n[i] into the YMCK γ-calibration table and the output value LD[i] (described as error hereinafter) will be minimum,

$$\mathrm{error}=\Sigma wi\cdot(LD[i]-E[n[i]])^2$$

wherein wi is weight to an input value to the i-th YMCK γ calibration table. In this step, if an error for the highlight section is large, a desired result can not be obtained, so that the weight wi for the highlight section is made larger to make the error as small as possible.

Similarly, curvature h for a highlight section which should have a minimum error is obtained (step **S4003**), and then curvature s for a shadowed error which should also have a minimum error is obtained (step **S4004**). The (h_min, m_min, s_min) obtained as described above and IDMAX are used as new curvature of the calibrated gradation curve.

Next description is made for a method of setting a calibration value for RGB signals with an external device and a particular example of input data from the device with reference to FIG. **20** through FIG. **23**. FIG. **20** is a general block diagram showing an example of configuration for setting and inputting calibration values for RGB signals; FIG. **21** is a block diagram showing electric configuration of the system shown in FIG. **20**; FIG. **22** is a flow chart showing a sequence for setting and inputting calibration values for RGB signals in a form according to the second embodiment of the present invention; and FIG. **23** is a flat view showing an example of color patch transferred onto transfer paper.

As shown in FIG. **20**, a computer **321**, which is a computing device for computing calibration values for RGB signals, is connected with a wired communication means to the main body of copying machine **101** so that bi-directional communication can be made. The computer **321** comprises a computer for control which can also process data. It should be noted that the main body of copying machine **101** and the computer **321** may be connected to each other with a radio communicating means. Copying machine **101** is arranged to accept a YMCK color patch **324** and discharge a transfer paper **311**, as described hereinafter.

As shown by the block diagram in FIG. **21**, the main body of copying machine **101** has a non-volatile RAM **322**, and reads color patch having a known spectral reflection characteristic. A memory device **323** is connected to the computer **321**.

To describe a sequence for preparing calibration values for RGB signals with the devices with reference to the flowchart shown in FIG. **22**, a YMCK color patch **324** having a known spectral reflection characteristics is placed on a contact glass **118** of the main body of the copying

machine (step S5001). The color patch **324** comprises a color patch printed with YMCK ink or the like when transferred onto transfer paper **311** as shown in FIG. **23**. FIG. **23** shows two types of color tone for each of YMCK, but the color tone may be one type. Then with the scanner **401** of the main body of the copying machine **101**, the color patch **324** is read, and read values for RGB signals are obtained (step S5002). The read values for this color patch **324** are down-loaded to a computer **321** which is an external computing device (step S5003).

The read values V[t][s](t=W, Y, M, C, or K: s=R, G, or B) for RGB signals for the color patch **324** down-loaded to the computer **321** are compared to the read values v0[t][s] (t=Y, M, C, or K: s=R, G, or B) for RGB signals read with a CCD having a standard spectral characteristic, and a ratio k[t][s] (t=Y, M, C, or K: s=R, G, or B) for each is obtained (step S5004). It should be noted that this computing may be executed in the side of the main body of the copying machine **101**. Then calibration values for RGB signals obtained from the computer **321** are up-loaded to the main body of the copying machine **101** (step S5005), and the main body of the copying machine **101** stores the obtained calibration values for RGB signals in the non-volatile RAM **322** (step S5006).

Calibration values for RGB signals are prepared with the computer **321** as described above, and the calibration values are transferred to the main body of the copying machine **101** and stored in the non-volatile RAM **322** in the main body of the copying machine **101**. The calibration values for RGB signals stored in the non-volatile RAM **322** are transferred to the CPU **130** just after power for the main body of the copying machine **101** is turned ON, and are stored in the RAM **132** of the CPU **130**. The calibration value for RGB signals stored in the RAM **132** of the CPU **130** are used in execution of the ACC described above.

The processing is executed as described below.

$$\Delta v[t][s]=v[W][s]-v[t][s] \tag{15}$$

$$\Delta v0[t][s]=v0[W][s]-v0[t][s] \tag{16}$$

$$k[t][s]=\Delta v0[t][s]/\Delta v[t][s] \tag{17}$$

Herein t=w is a read value for white as a standard. It should be noted that the value may be for white of the transfer paper **311**, or may be an ideal white such as Δv[t][s] for an 8-bit signal if spectral reflection characteristic is known.

In the example described above, the color patch **324** painted with ink or the like was used, but printed-out a toner patch outputted from the main body of the copying machine **101** may be used. Description is made for this case with reference to FIG. **24** and FIG. **25**. FIG. **24** is a block diagram showing another example of setting and inputting calibration values for RGB signals, and FIG. **25** is a flowchart showing a sequence for setting and inputting calibration values for RGB signals in FIG. **24**.

As shown in FIG. **24**, in this example, the configuration is the same as that shown in FIG. **21** excluding the point that a toner patch **324***a* is obtained from the main body of the copying machine **101**, so that duplicated description is omitted herein. Also in the flow chart in FIG. **25** showing a sequence for preparation, the sequence from step S**6002** to step S**6007** is completely the same as a sequence from step S**5001** to step **5006** in FIG. **22** excluding the step **6001** for placing the color patch **324** on the contact glass **118** of the basic body of the copying machine **101**, so that also description of the steps is omitted herein.

To know the spectral reflection characteristic, the spectral reflection characteristic ρ(t, λ) (wavelength λ [n m], t=W, Y, M, C, or B) is measured using the spectrographic color measure or the like, and at the same time it may be computed from the spectral transmission characteristic τ [s, λ](s=R, G, or B) of a standard CCD as well as from the spectral characteristic E0(λ) for a standard light source through the following expression.

$$\Delta v0[t][s]=A\ E0(\lambda)\rho(t,\lambda)\tau 0(s,\lambda)d\lambda \tag{18}$$

wherein A is a proportional al constant, and λ is a wavelength.

Next description is made for still another example of a case where calibration values for RGB signals are computed using the expression (18) with reference to FIG. **26** and FIG. **29**. FIG. **26** is a general block diagram showing still another example of configuration for setting and inputting calibration values for RGB signals; FIG. **27** is a block diagram showing electric configuration of the system shown in FIG. **26**; FIG. **28** is a block diagram showing electric configuration of a case where a color patch prepared with toner in the configuration shown in FIG. **26** is used; and FIG. **29** is a flow chart showing a sequence for setting and inputting calibration values for RGB signals in FIG. **27** and FIG. **28**.

The configuration shown in FIG. **26** are the same as that shown in FIG. **20** excluding the point that a spectrographic color measuring instrument **331** is connected to the computer **321**. Also in the block diagram shown in FIG. **27**, the image density adjustor **332** comprises a computer **321**, a storage device **323**, and the spectrographic color measuring instrument **331**. Further, in a case where a toner patch **324***a* prepared with toner is used as a color patch, a toner patch **324***a* is prepared with the main body of the copying machine **101**, so that the blocks as shown in FIG. **28** are provided.

To describe a sequence for preparing calibration values for RGB signals with the configuration as described above with reference to the flowchart shown in FIG. **29**, at first a color patch is outputted (step S7001). Then the YMCK color patch having a known spectral reflection characteristic is placed on the contact glass **118** of the document base of the main body of the copying machine **101** (step S7002). Then, with the color scanner **401** of the main body of the copying machine **101**, the color patch is read to obtain read values for RGB signals (step S7003). On the other hand, in the computer **321** which is an external computing device, read values for the color patch from the main body of the copying machine **101** is down-loaded (step S7004), and the outputted color patch outputted from the main body of the copying machine **101** is read with the spectrographic color measuring instrument **331** (step S7005).

Then, read values for RGB v0[t][s] (t=W, Y, M, C, or K:s=R, G, or B) when read with a CCD having a standard spectral characteristic are computed from the read values v[t][s] (t=W, Y, M, C, or K: s=R, G, or B) for RGB of the color patch down-loaded into the computer **321** as well as a result of measurement of a spectral reflection factor through the expression (18), and a ratio k[t][s] (t=W, Y, M, C, or K: s=R, G, or B) for each of RGB is obtained (step **7006**). Then the calibration values for RGB signals obtained from the computer **321** are up-loaded to the main body of the copying machine **101** (step **7007**) and are stored in the non-volatile RAM **322** in the main body of the copying machine **101** (step **7008**).

Although the computer **321** is used as an external device in the example described above, the processing through the expression (17) may be executed by previously storing the values for the expression (16) in the non-volatile RAM **322**

or ROM 416 of the main body of the copying machine 101. Description is made below for the sequence in this case with reference to the flowchart shown in FIG. 30. Namely, the YMCK gradation pattern (color patch) is placed on the contact glass 118 of a document base of the main body of the copying machine 101 (step S8001), and the color patch is read with the color scanner 401 of the main body of the copying machine 101 to obtain read values for RGB signals (step 8002). Then read value v[t][s] (t=W, Y, M, C, or K: s=R, G, or B) for RGB of the color patch are compared to the read value v0[t][s] (t=W, Y, M, C or K: S=R, G, or B) for RGB when read with a CCD having a standard spectral characteristic and previously stored therein, and a ration k[t][s] (t=W, Y, M, C, or K: s=R, G, or B) for each is obtained (step 8003). Then the calibration values for RGB signals obtained as described above are stored in the non-volatile RAM 322 in the main body of the copying machine 101 (step 8004).

It should be noted that, in a case where a printer controller is connected to use the image forming apparatus as a printer, when outputting data from the host computer connected to the printer controller, or by preparing a command for setting the calibration values in a printer set command, the calibration values for RGB may be set. Also in a case where a memory card can be used, the calibration values may be stored in the memory card so that the calibration values can be read out when the image forming apparatus is used.

In the first embodiment described above, an image signal conversion table is prepared and selected according to read values read for a gradation pattern, but also an image signal conversion table is prepared and selected according to read signals read for gradation patterns formed on a transfer member as well as to reference data (gradation target data) corresponding to read signals for gradation patterns stored in a storing means. Description is made for the embodiment below. It should be noted that, in the second embodiment, the same reference numerals are assigned to sections corresponding to those in the first embodiment, and description thereof is omitted herein.

The reference data consists of input values n into a gradation conversion table (n=0, 1, 2, . . . , 255) and target values for values read by a scanner 401 (r[t][i], g[t][i], b[t][i]), and the reference data is expressed as follows:

$$Ar[t][n](0 \leq n \leq 255,\ t=Y, M, C, \text{ or } K)$$

$$Ag[t][n](0 \leq n \leq 255,\ t=Y, M, C, \text{ or } K)$$

$$Ab[t][n](0 \leq n \leq 255,\ t=Y, M, C, \text{ or } K) \qquad (19)$$

Herein Ar, Ag, and Ab are reference data for a red signal, a green signal, and a blue signal respectively, while YMCK indicates a color of toner.

The above expression (19) indicates that a probable input value into a gradation conversion table, namely reference data corresponding to any of 256 values from 0 to 255 are stored on a memory with the processing for 8-bit signal. By storing reference data consisting of 256 values as described above, the processing described later can be simplified, but to save a memory space required for storing the reference data, by storing the following set with the reference data obtained through the expression (19) and corresponding to several value of n[i] (in this case, 16 types of value) with n[0]=0, n[i]=26×i−5 (i=1, 2, . . . , 10) as an example thereof:

$$n[i](0 \leq n \leq 255,\ i=0, 1, \ldots, 10)$$

$$Ar[t][n[i]](0 \leq n \leq 255,\ i=0, 1, \ldots, 10\ t=Y, M, C, \text{ or } K)$$

$$Ag[t][n[i]](0 \leq n \leq 255,\ i=0, 1, \ldots, 10\ t=Y, M, C, \text{ or } K)$$

$$Ab[t][n[i]](0 \leq n \leq 255,\ i=0, 1, \ldots, 10\ t=Y, M, C, \text{ or } K)$$

and reference data Ar[t][n[i]] corresponding to n (n=1 to 20 in the above case) other than n[i] (i=0, 1, 2, . . . , 10) may be computed by interpolation as described below. As one of the examples, the value may be computed by means of interpolation using reference data Ar, g, b[t][n[i]], Ar, g, b[t][n[i+1]] corresponding to n[i]≦n≦n[i+1] (for n=1 to 20, i=0, n[0]=0, n[1]=21).

On the other hand, in a RAM 417, percentages of RGB components in the reference data for read values for the patterns are stored as indicated by the expression (10). K[s][t] in the expression (10) takes a value close to 1. However, as indicated by the Expression 9, inside a copying machine, the value is stored as integral number data. A value of k[s][t] obtained as described above which is a calibration value for the RGB signals is like that as shown in Table 1 above.

The calibration data for the RGB signals shown in Table 1 is, as shown in FIG. 19, displayed on a display screen 305 of an operating section of the main body of the copying machine 101, and the numerical values can be inputted by pressing a section corresponding to a section to be displayed with a finger. The inputted data is stored in the RAM 417.

As one of the examples, description is made below for a case of t=c (cyan). GGB components of the reference data for cyan toner are calibrated as follows:

$$Ar[C][n[i]]=Ar[W]+(Ar[C][n[i]]-Ar[W])\times k[r][C]$$

$$Ag[C][n[i]]=Ag[W]+(Ag[C][n[i]]-Ag[W])\times k[g][C]$$

$$Ab[C][n[i]]=Ab[W]+(Ab[C][n[i]]-Ab[W])\times k[b][C] \qquad (21)$$

It should be noted that i=0, 1, 2, . . . , 10 in the expression (21) above. Herein (Arl[C][n[i], Agl[C][n[i], Abl[C][n[i]) indicates RGB components in reference data after calibration, and (Ar[C][n[i]], Ag[C][n[i]], Ab[C][n[i]] indicates reference data before calibration. Also Ar[W], Ag[W], and Ab[W] are RGB signals when a white color (the brightest color to the scanner 401 to be used) is read respectively. In a case where a red value is an 8-bit signal, this value is in a range from 0 to 25, and value 0 indicates the darkest image density, namely a quantity of light detected by a CCD in the scanner 401 when an object with a low reflection factor or a low transmission factor is read, and value 255 indicates the brightest image density, namely a quantity of light detected by a CCD in the scanner 401 when an object with a high reflection factor or a high transmission factor is read.

It should be noted that each value may be set as follows in practical operation, although the precision becomes somewhat lower:

$$Ar[W]=Ar[C][0]$$

$$Ag[W]=Ag[C][0]$$

$$Ab[W]=Ab[C][0]$$

Herein, Ar[C][0], Ag[C][0], and Ab[C][0] are values obtained when the background color section of the paper is read. It should be noted that, when reading a background color section of paper, it is possible to prevent the precision from becoming lower by setting several sheets of white paper to make up so-called the white back so that the backing for the paper will not become dark.

As another example, in a case of t=C (cyan), practically the processing can be executed by setting each value as follows:

$$Ar1[C]\,[n[i]] = Ar[W] + (Ar[C]\,[n[i]] \times k[r]\,[C] \quad (22)$$

$$Ag1[C]\,[n[i]] = Ag[W] + (Ag[C]\,[n[i]] \times k[g]\,[C]$$

$$Ab1[C]\,[n[i]] = Ab[W] + (Ab[C]\,[n[i]] - Ab[W]) \times k[b]\,[C]$$

Herein, i in the expression (22) is in a range from 0 to 10. However, in a case of i=0, n[**0**], namely in a case where an input value into the gradation conversion table is 0 (zero), calibration by the expression (22) should not be performed. The values of k[r][C], k[g][C], and k[b][C] used in the expression (22) are not equal to the values of k[r][C], k[g][C], and k[b][C] used in the expression (21) , and it is necessary to change the numerical values to appropriate ones for each expression. To simplify the processing, the (Ar[C][n[i]], Agl[C][n[i]], Abl[C][n[i]]) is modified to (Ar [t][n[i]], Ag[t][n[i]], Ab[t][n[i]]) and is used in the processing described below.

Next, description is made for a sequence for producing a gradation conversion table (LUT) executed during execution of ACC in a γ-calibrating circuit **410** which is a γ-conversion processing section.

Image signals for complementary colors for YMC toners are blue, green, and red respectively, and to simplify the processing, of the reference data Ar[t][i], Ag[t][i], and Ab[t][i], the reference data Ab[t][i], Ag[t][i], and Ar[t][i] for complementary colors for the toners are used. This treatment is effective in a case where the spectral (reflection) characteristic of used toner does not change largely, namely in a case where the color taste does not change. Herein to simplify the description, the following expression is used:

$$A[t][n[i]](0 \leqq n[i] \leqq 255,\ i=0, 1, \ldots, 10;\ t=C, M, Y)$$

For black toner, adequate preciseness is obtained by using either one of the RGB image signals, but therein the G (green) component is used.

Similarly, also the read signal is expressed using only an image signal for the complementary color as follows:

$$a[t][i](i=0, 1, \ldots, 9;\ t=C, M, Y, K)$$

Furthermore reference data A[t][i] for toner t for a certain color (t=C, M, Y, K) and a written value a[t][i] for a laser beam (LD) are expressed as A[i] and a[t][i] in abbreviated forms respectively.

Next description is made for a computing sequence with reference to FIG. 31. FIG. 31 is a flowchart showing a sequence for preparing a gradation conversion table in execution of ACC.

At first, an input value required for preparation of a YMCK γ-calibration table is computed (step S**3001**). Herein it is assumed that n[i]=11[h]×i (i=0, 1, . . . , imax=15). Then, the reference data A[n] is calibrated with a calibration value k[s][t] for RGB signal according to the sequence described above (step S**3002**). Then the reference data A[n] is calibrated according to an image density which can be outputted from the printer **412** (step **3002***a*). Herein, it is assumed that a read value for a laser bean which makes it possible to obtain the maximum image density obtainable with the printer **412** is FFh (displayed in a form of hexadecimal form), and also that the read value m [FFh] for the pattern then is mmax. Also it is assumed that reference data not calibrated in a range from the low image density to the intermediate image density is A[i] (i=0, 1, . . . , i1); reference data not calibrated in the high image density side is A[i] (i=i2+1, . . . , imax−1) (i2≧i1, i2≦imax−10, and reference data to be calibrated in the area is A[i](i=i1+1, . . . , i2).

Next description is made for a concrete computing method assuming an image signal not subjected to RGB γ-conversion which is proportional to a reflection factor of the document. Of the reference data not subjected to calibration, the difference Δref is computed from the reference data A[i2+1] with the lowest image density in the high image density section as well as from the reference data A[i1] with the lowest image density in the low image density section.

Namely, the following expression is applicable:

$$\Delta ref = A[i1] - A[i2+1] \quad (23)$$

On the other hand, in a case of reflection factor linear or a brightness linear not requiring RGB γ-conversion which is a process for inversion, the Δref is larger than 0. Also the different Δdet is computed from the read value mmax for the pattern with the maximum image density obtainable with the printer **412**. Namely the following expression is applicable:

$$\Delta det = A[i1] - mmax \quad (24)$$

From the expressions (14) and (15) above, the reference data A[i] (i=i1+1, . . . , i2) having been subjected to calibration of the high density section is:

$$A[i] = A[i1] + (A[i] - A[i1]) \times (\Delta det / \Delta ref)\ (i=i1, i1+2, \ldots, i2-1, i2) \quad (25)$$

Then an image signal n[i] read by the scanner **401** corresponding to n[i] obtained in step **3001** is obtained from the reference data A[n] (step **3003**). Actually, the reference data A (n[j] (0≦n[j] 255, j=0, 1, . . . , jmax, n[j]≦n[k] for i≦k) corresponding to discrete n[j] is set as follows. Namely, j (0≦j≦jmax) for n[j]≦n[i]<n[j+1] is obtained.

In a case of an 8-bit image signal, by obtaining reference data assuming that n[0]=0, n[jmax]=255, n[jmax+1]=n [jmax]+1, and A[jmax+1]=A[jmax], the computing is simplified.

Also , the smaller the gap n[j] in the reference data is, the higher a degree of preciseness of the finally obtained γ-calibration is.

A target value m[i] is obtained from j obtained as described above through the following expression:

$$m[i] = A[j] + A[j] + (A[j+1] - A[i]) \cdot (n[i] - n[j]) / (n[i+1] - n[i]) \quad (26)$$

Herein, interpolation is performed with a linear expression, but interpolation may be formed with a high-order function or a spline function. In that case,

$$m[i] = f(n[i])$$

Also in a case of a the k-th function, the Expression 17 described above may be used.

Then a written value LD[i] for LD to obtain the target value m[i] obtained in step S3003 is obtained through a sequence similar to that in step **3003** (step **3004**).

Namely, when image signal data not having been subjected to RGB γ-conversion is processed, as a value of LD becomes larger, a value of a [LD] becomes smaller. In other words, in contrast to

$$LD[k] < LD(k+1)$$

the following expression is applicable:

$$a[LD[k]] \geqq a[LD[k+1]]$$

Herein an LD value when a pattern is formed can take 10 values of LD [k]=00h, 11h, 22h, . . . , 66h, 88h, AAh, FFh.

(k=0, 1, . . . , 9). This type of setting is employed because, as values for a quantity of deposited toner read by the scanner **401** largely changes in an area with image density corresponding to a small quantity of deposited toner, gap between written value LD[k] for a pattern is made smaller to read the area, and also as values for a quantity of deposited toner read by the scanner **401** little changes in an area with image density corresponding to a large quantity of deposited area, the gap be made larger to read the area.

The merits provided by forming a pattern with LD read values as described above are that, as compared to a case where the number of patterns is increased as indicated by LD[k]=00h, 11h, 22h, . . . , EEh, FFh (16 patterns in total), a consumption rate of toner can be suppressed, and that LD written values little change in a high image density area, and the scheme as described above is employed because, as read values easily changes due to non-uniformity in potential on a photosensitive body, non-uniformity in deposition of toner, and also non-uniformity in potential on toner, making smaller a gap between LD written values is not always effective for improve the preciseness.

Herein to LD [k] satisfying the following expression:

$$a[LD[k]] \geqq m[i] > a[LD[k+1]]$$

the following expression is applied:

$$LD[i] = LD[k] + (LD[k+1] - LD[k]) \cdot (m[i] - a[LD[k]]) / (aLD[k+1] - a[LD[k]])$$

In a case of $0 \leqq k \leqq kmax$ ($kmax>0$), if a[LD[kmax]] is larger than m[i] (if image density for a target value obtained from the reference data is high), the following expression is used:

$$LD[i] = LD[k] + (LD[kmax] - LD[kmax-1]) \cdot (m[i] - a[LD[kmax-1]]) / (aLD[kmax] - a[LD[kmax-1]])$$

and estimation is made by performing by extrapolation with a linear function. In addition to use of a linear function, other methods such as use of logarithm may be employed for extrapolation.

With this a set (n[i], LD[i]) (i=0, 1, . . . , 15) of an input value n[i] into a YMCK γ-calibration table and an output value LD[i] can be obtained.

And according to the obtained (n[i], LD[i]) (i=0, 1, . . . , 15) interpolation is performed with a spline function or the like, or a γ-calibration table in the ROM **416** is selected (step **3005**).

Sections, operations and processes not specifically described herein are the same as those in the first embodiment.

As understood from the description above, with an image forming apparatus according to the present invention, it is possible to correct spectral sensitivity of an image reading means varying unit by unit and to obtain a gradation calibration table for obtaining good gradations. Also it is possible to prepare a YMCK gradation calibration table for obtaining good color balance in a color image forming apparatus.

With an image forming apparatus according to the present invention, in a case where spectral (transmission) characteristics changes due to change of an image reading means during passage of time, or even in a case where spectral (transmission) characteristic of toner being used changes, it is possible to always obtain a correct value by setting a ratio between a plurality of signal read values each having different spectral sensitivity.

With an image forming apparatus according to the present invention; a service man or a user can easily obtain a desired image by freely changing a calibration value previously set in an operating section of an image forming apparatus.

With an image forming apparatus according to the present invention, when non-uniformity of spectral sensitivity of an image forming means which will vary from unit to unit can be calibrated in the assembly step by inputting a value for calibration from the device provided outside the image forming apparatus, and with this feature a calibration value can easily be set in each image forming apparatus.

With an image forming apparatus according to the present invention, even in a case where characteristics of a machine changes during passage of time or a color characteristic of toner changes, an appropriate value can easily be set as a calibration value according to the change, and a serviceman or a user can set an appropriate calibration value with simple operations.

With an image forming apparatus according to the present invention, it is possible to correct spectral sensitivity of an image reading means which varies unit by unit and also to prepare a YMCK gradation calibration table for obtaining good color balance and gradations by executing ACC.

With an image forming apparatus according to the present invention, in a case where spectral (transmission) characteristic of an image reading means changes during passage of time, or in a case where spectral (reflection) characteristic of toner being used changes, a ratio between RGB read values for YMCK toner being used for the image reading means can be inputted according to the necessity, and a read value for YMCK toner can always be calibrated to an appropriate value.

With an image forming apparatus according to the present invention, a serviceman or a user can input an appropriate calibration value into an operating section of an image forming apparatus, so that a gradation calibration table for obtaining good color balance and gradations can be obtained by executing ACC.

With an image forming apparatus according to the present invention, data for calibrating non-uniformity in spectral sensitivity of an image reading means which varies for each image forming apparatus can be prepared or set with a device provided outside the image forming apparatus in the assembly step, so that data can rapidly be set in the image forming apparatus.

With an image forming apparatus according to the present invention, even if machine characteristic changes during passage of time or color characteristic of toner changes, it is possible to have an appropriate value stored as a calibration value according to the change, and a gradation calibration table for obtaining good color balance and gradations can be obtained by executing ACC.

This application is based on Japanese patent application Nos. HEI 8-296542, HEI 8-116723 and HEI 9-109257 filed in the Japanese Patent Office on Nov. 8, 1996, May 10, 1996 and Apr. 25, 1997, respectively, the entire contents of which are hereby incorporated by reference.

Although the invention has been described with respect to a specific embodiment for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art which fairly fall within the basic teaching herein set forth.

What is claimed is:

1. An image forming apparatus comprising:

a reading means for optically scanning and reading a document image;

a means for converting an input image signal from said reading means to an output image signal by referring an

image signal conversion table, and outputting the converted signal;

a writing means for writing image information on an image carrier according to said output image signal;

a means for transfer the image on said image carrier onto a transfer member to form the image;

a means for generating a plurality of gradation patterns; and

a means for updating and selecting an image signal conversion table according to read values obtained by reading the gradation patterns generated and transferred by said generating means onto transfer paper with said reading means for reading an image; wherein a read signal for said gradation patterns comprises a plurality of signals each having different spectral sensitivity, and a memory for storing therein calibration factors for said plurality of signals each having different spectral sensitivity is provided to correct the read signals for said gradation patterns according to said calibration factor from said memory.

2. An image forming apparatus according to claim 1 further comprising a means for setting a ratio between read values for said plurality of signals each having different spectral sensitivity.

3. An image forming apparatus according to claim 2; wherein said means for setting a ratio between read values sets the ratio between read values from read values for said patterns as well as from read values for a plurality of signals previously stored therein.

4. An image forming apparatus according to claim 2; wherein setting by said means for setting a ratio between read values is performed by inputting data from an operating section of the image forming apparatus.

5. An image forming apparatus according to claim 4; wherein said means for setting a ratio between read values sets the ratio between read values from read values for said patterns as well as from read values for a plurality of signals previously stored therein.

6. An image forming apparatus according to claim 2; wherein said means for setting a ratio between said read values is provided outside the image forming apparatus and inputs said ratio between read values into said image forming apparatus from the outside thereof.

7. An image forming apparatus according to claim 6; wherein said means for setting a ratio between read values sets the ratio between read values from read values for said patterns as well as from read values for a plurality of signals previously stored therein.

8. An image forming apparatus comprising:

a means for optically scanning and reading a document image;

a means for converting an input image signal from said reading means to an output image signal by referring to an image signal conversion table and outputting the converted signal;

a writing means for writing image information onto an image carrier according to said output image signal;

a means for transferring the image on said image carrier onto a transfer member to form the image;

a means for generating a plurality of gradation patterns; and

a means for updating and selecting an image signal conversion table according to read signals for gradation patterns generated and formed on a transfer member by said generating means and read by said image reading means as well as to reference data which is gradation target data corresponding to the read signals for said gradation patterns stored in the storing means; wherein said reference data comprises a plurality of signals each having different spectral sensitivity, and said image forming apparatus has a memory for storing calibration factors for the plurality of signals each having different spectral sensitivity and a means for calibrating said reference data according to said calibration factors.

9. An image forming apparatus according to claim 8 further comprising a means for setting a ratio between said reference data having different spectral sensitivity respectively.

10. An image forming apparatus according to claim 9; wherein setting by said means for setting a ratio between reference data having spectral sensitivity is performed by inputting data from an operating section of the image forming apparatus.

11. An image forming apparatus according to claim 9; wherein said means for setting a ratio between reference data having different spectral sensitivity is provided outside the image forming apparatus and the reference data from said setting means is inputted into said image forming apparatus.

12. An image forming apparatus according claim 9; wherein said means for setting a ratio between reference data having different spectral sensitivity sets a ratio between read values from read values for said patterns as well as from read values for a plurality of signals previously stored therein.

* * * * *

US005521637A

United States Patent [19]

Asaida et al.

[11] Patent Number: 5,521,637

[45] Date of Patent: May 28, 1996

[54] SOLID STATE IMAGE PICK-UP APPARATUS FOR CONVERTING THE DATA CLOCK RATE OF THE GENERATED PICTURE DATA SIGNALS

[75] Inventors: Takashi Asaida; Jun Hattori, both of Kanagawa, Japan

[73] Assignee: Sony Corporation, Tokyo, Japan

[21] Appl. No.: 503,424

[22] Filed: Jul. 17, 1995

Related U.S. Application Data

[63] Continuation of Ser. No. 133,296, Oct. 8, 1993, abandoned.

[30] **Foreign Application Priority Data**

Oct. 9, 1992 [JP] Japan 4-297766

[51] Int. Cl.^{6} H04N 5/228

[52] U.S. Cl. 348/222; 348/272; 348/265; 348/492; 348/71

[58] Field of Search 348/71, 265, 272, 348/492, 222, 266, 392, 494; H04N 9/04, 7/18, 9/09, 3/14, 5/335, 9/083, 11/12, 5/228, 9/07, 7/12, 11/02, 11/04

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,870,661	9/1989	Yamada et al.	341/61
5,043,798	8/1991	Emori	348/392
5,136,379	8/1992	Ishii	348/392
5,272,524	12/1993	Nagumo et al.	358/41
5,359,428	10/1994	Kubota et al.	358/335

FOREIGN PATENT DOCUMENTS

0420612	4/1991	European Pat. Off.
0520759	12/1992	European Pat. Off.
2069795	8/1981	United Kingdom.

OTHER PUBLICATIONS

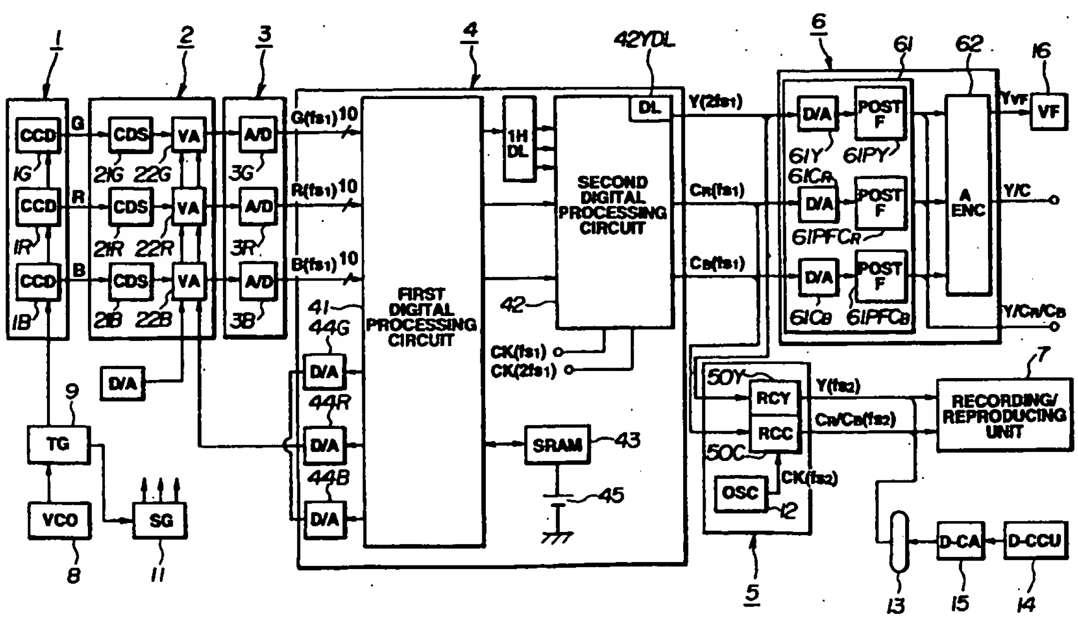
SMPTE Journal, vol. 100, No. 1, Jan. 1991, U.S., pp. 19–22 "A complete post-production system for all video formats."

Primary Examiner—Safet Metjahic
Assistant Examiner—Nina M. West
Attorney, Agent, or Firm—William S. Frommer; Alvin Sinderbrand

[57] **ABSTRACT**

A solid-state image pickup apparatus for generating image pickup signals produced by a solid-state image sensor. The image sensor is driven at a data rate of f_{s1} with a predetermined phase. Digital luminance signal Y and two digital chrominance signals C_R, C_B are generated by a first digital processing unit, operated at a clock rate related to the data rate of f_{s1}, from the digitized image pickup signals. These signals are then converted by a second digital processing unit into signals Y, C_R and C_B having a data rate related to f_{s2}. The second digital processing unit performs bandwidth limitations on these signals by a half band filter having a passband f_{s2}, $f_{s2}/2$ and $f_{s2}/2$ and performs data rate conversion of from $2f_{s1}$ to f_{s2}, from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$ and from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$, for outputting the low order linear phase finite impulse response sufficient to suppress high-order sideband components in the vicinity of $n \cdot 2f_{s1}$, $n \cdot f_{s1}$, and $n \cdot f_{s1}$, (n being a positive integer) in a form that can be down-sampled at f_{s2}, $f_{s2}/2$ or $f_{s2}/4$ and $f_{s2}/2$ or $f_{s2}/4$. The second digital processing unit can have a simplified construction when the characteristics of the half band filter are used to compensate for the band pass rollover characteristics of the rate-converting filter.

35 Claims, 19 Drawing Sheets



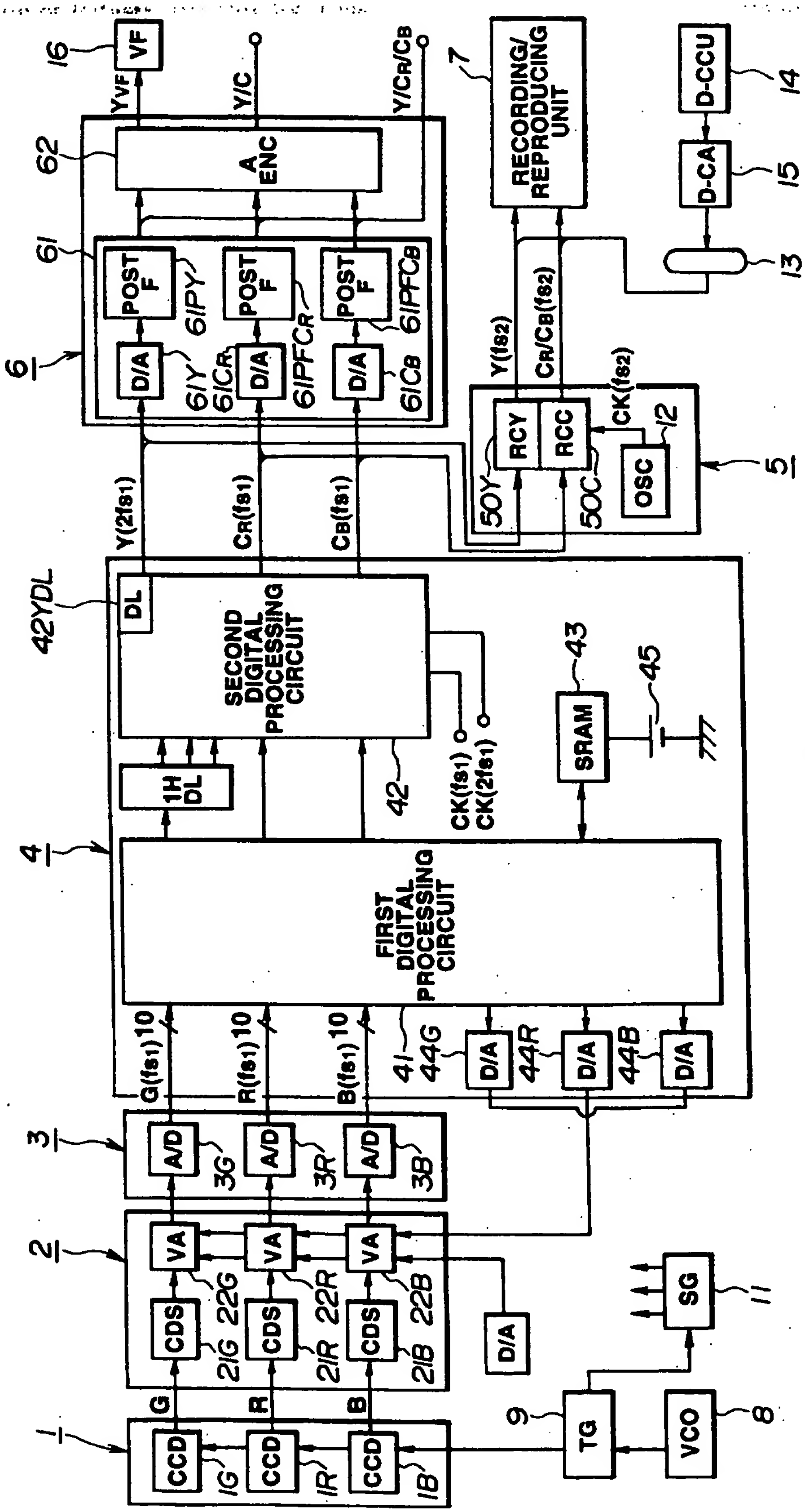
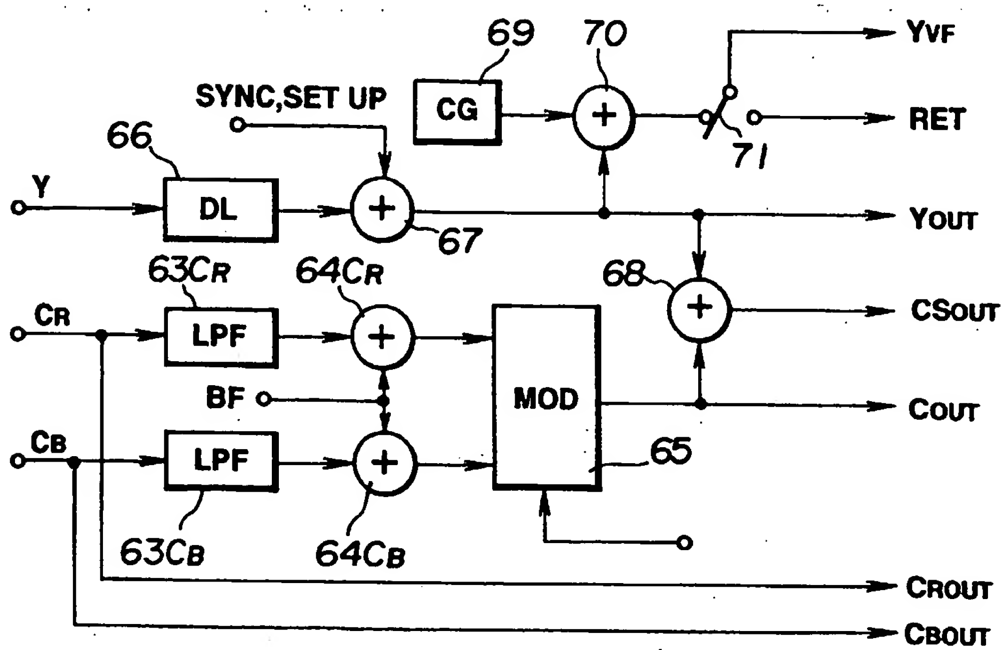
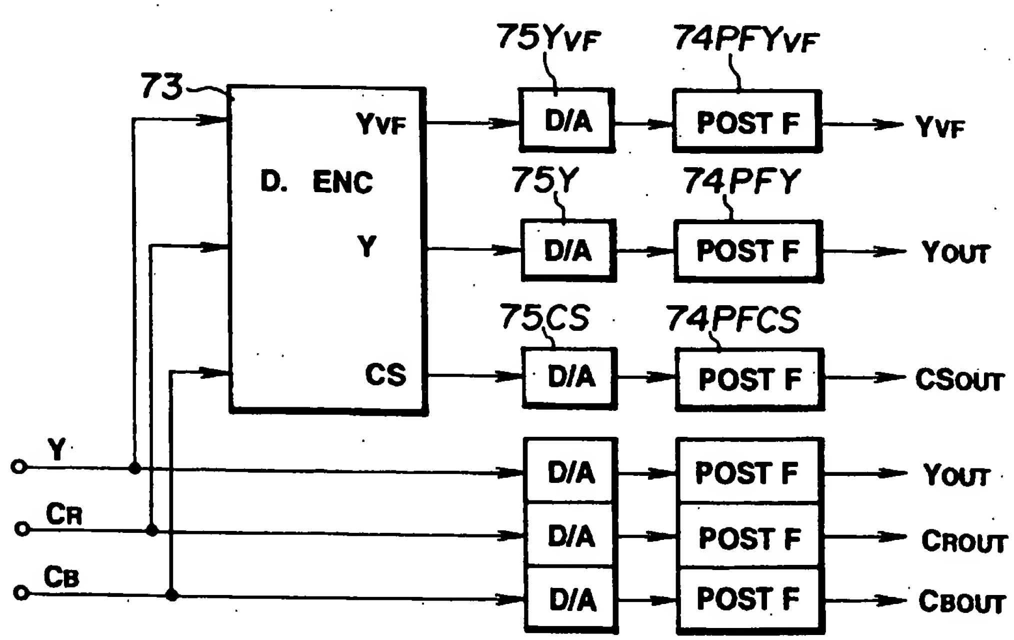

CCD
CDS
VA
A/D
D/A
TG
VCO
SG
FIRST DIGITAL PROCESSING CIRCUIT
SECOND DIGITAL PROCESSING CIRCUIT
1H DL
DL
SRAM
RCY
RCC
OSC
POST F
A ENC
VF
RECORDING/ REPRODUCING UNIT
D-CA
D-CCU
G(fs1)
R(fs1)
B(fs1)
Y(2fs1)
CR(fs1)
CB(fs1)
CK(fs1)
CK(2fs1)
Y(fs2)
CR/CB(fs2)
CK(fs2)
YVF
Y/C
Y/CR/CB

FIG.1



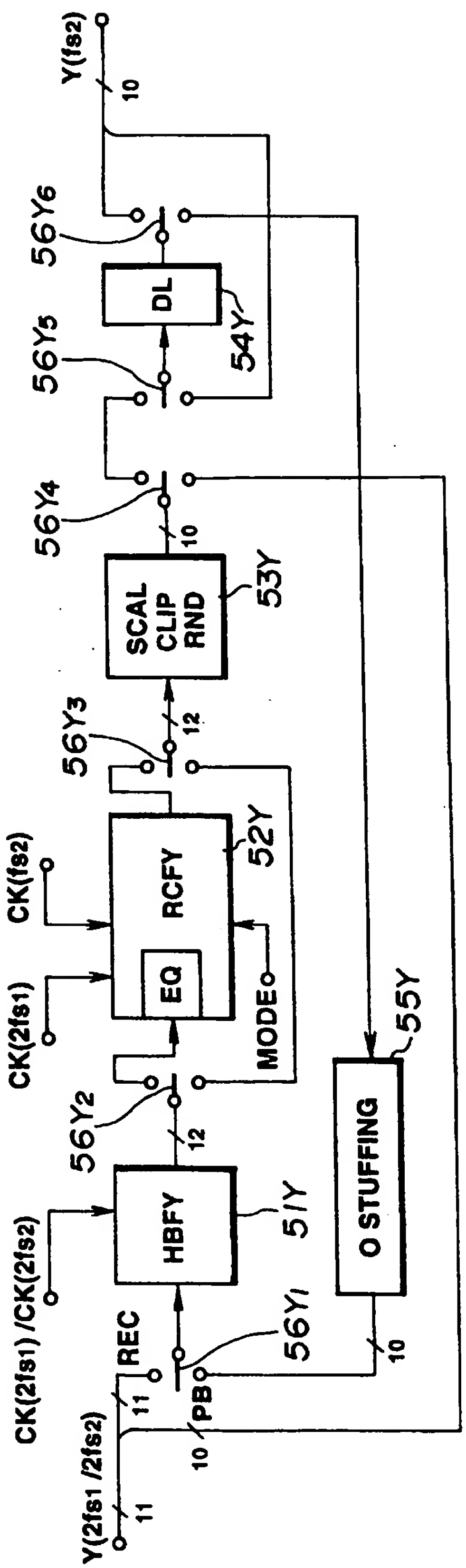
69
70
YVF
SYNC,SET UP
CG
RET
66
71
Y
DL
YOUT
67
63CR
64CR
68
CR
LPF
CSOUT
BF
MOD
COUT
CB
LPF
65
63CB
64CB
CROUT
CBOUT

FIG.2



75YVF
74PFYVF
73
YVF
D/A
POST F
YVF
D. ENC
75Y
74PFY
Y
D/A
POST F
YOUT
75CS
74PFCS
CS
D/A
POST F
CSOUT
Y
D/A
POST F
YOUT
CR
D/A
POST F
CROUT
CB
D/A
POST F
CBOUT

FIG.3



Y(fs2)
10
56Y6
DL
54Y
56Y5
56Y4
10
SCAL
CLIP
RND
53Y
56Y3
12
CK(fs2)
RCFY
EQ
52Y
CK(2fs1)
MODE
55Y
O STUFFING
56Y2
12
HBFY
51Y
CK(2fs1) /CK(2fs2)
REC
56Y1
10
11
PB
10
Y(2fs1 /2fs2)
11

FIG.4

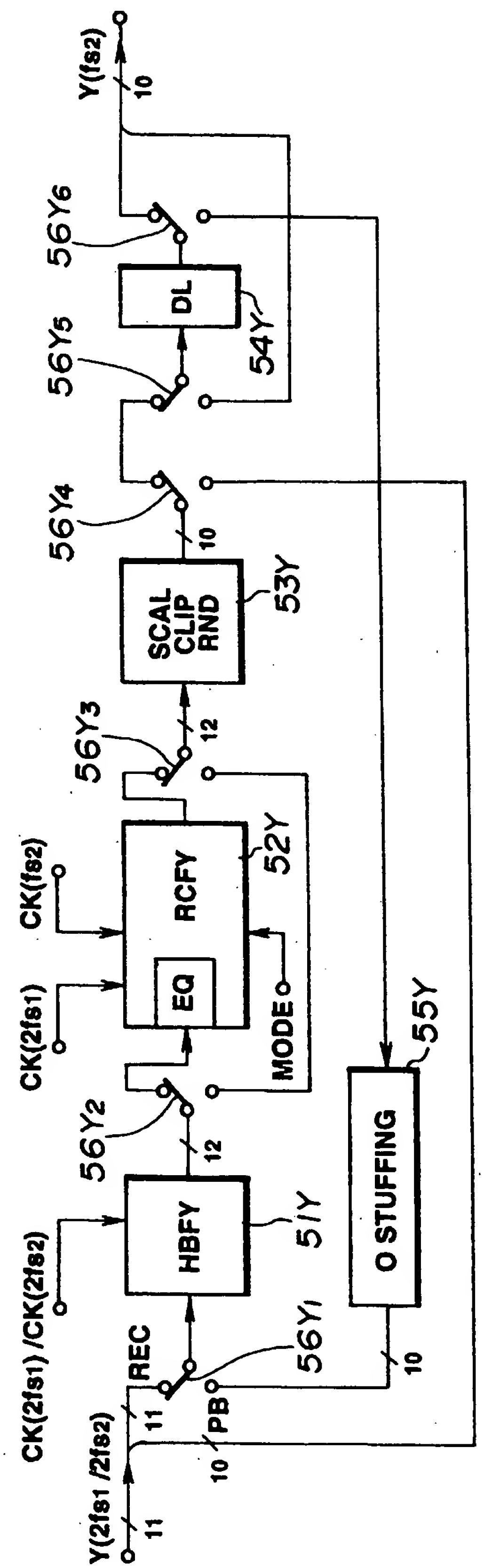

Y(2fs1 /2fs2)
11
REC
PB
10
56Y1
CK(2fs1) /CK(2fs2)
HBFY
51Y
12
56Y2
CK(2fs1)
CK(fs2)
EQ
RCFY
52Y
MODE
56Y3
12
SCAL
CLIP
RND
53Y
10
56Y4
56Y5
DL
54Y
56Y6
Y(fs2)
10
0 STUFFING
55Y
10

FIG.5

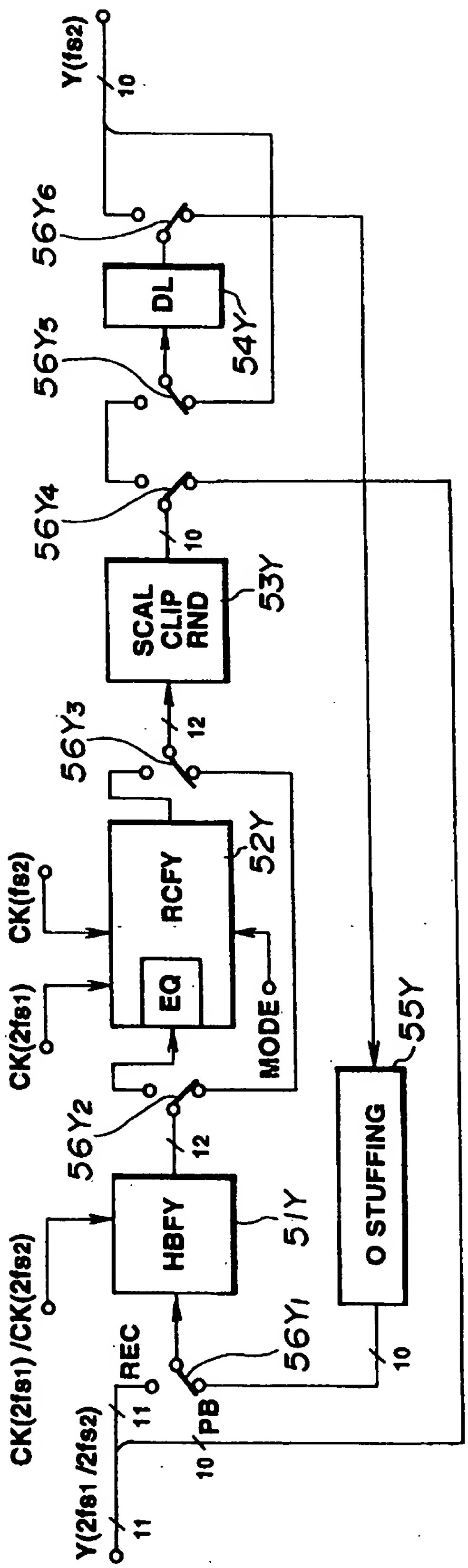

Y(fs2)
10
56Y6
DL
54Y
56Y5
56Y4
10
SCAL
CLIP
RND
53Y
56Y3
12
CK(fs2)
RCFY
52Y
CK(2fs1)
EQ
MODE
56Y2
12
HBFY
51Y
CK(2fs1) /CK(2fs2)
O STUFFING
55Y
56Y1
REC
PB
11
10
10
Y(2fs1 /2fs2)
11

FIG.6

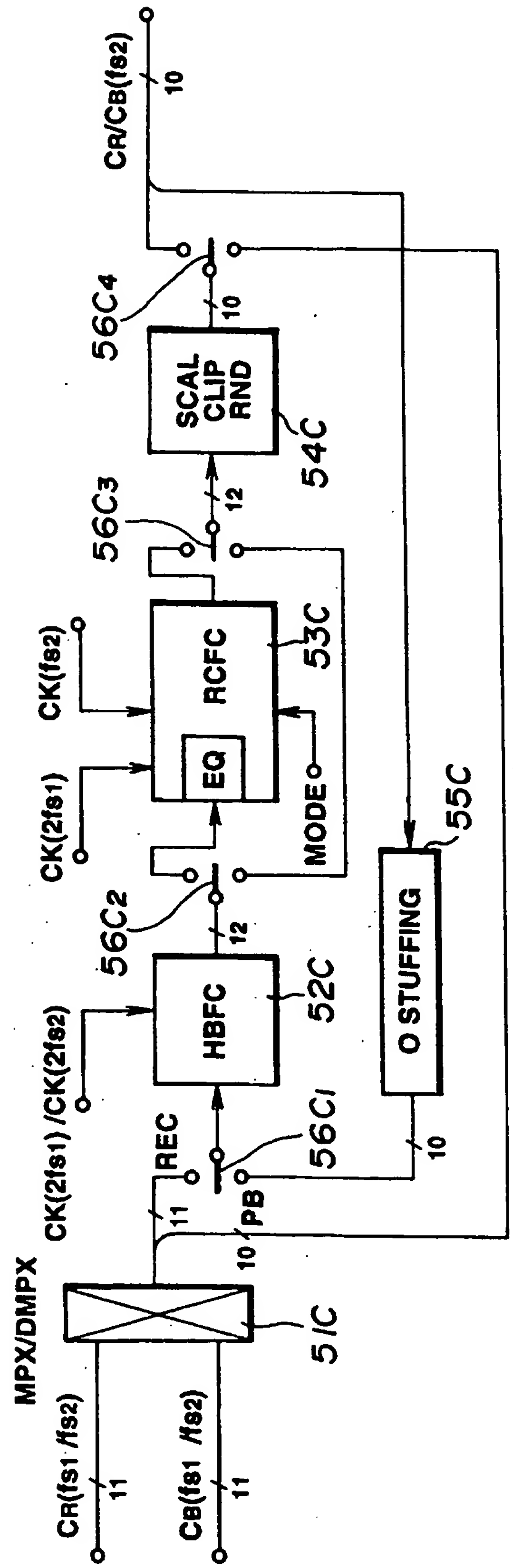

CR/CB(fs2)
10
56C4
SCAL CLIP RND
54C
56C3
12
RCFC
EQ
53C
CK(fs2)
CK(2fs1)
MODE
56C2
HBFC
52C
CK(2fs1) /CK(2fs2)
0 STUFFING
55C
REC
PB
56C1
11
MPX/DMPX
51C
CR(fs1 /fs2)
CB(fs1 /fs2)

FIG.7

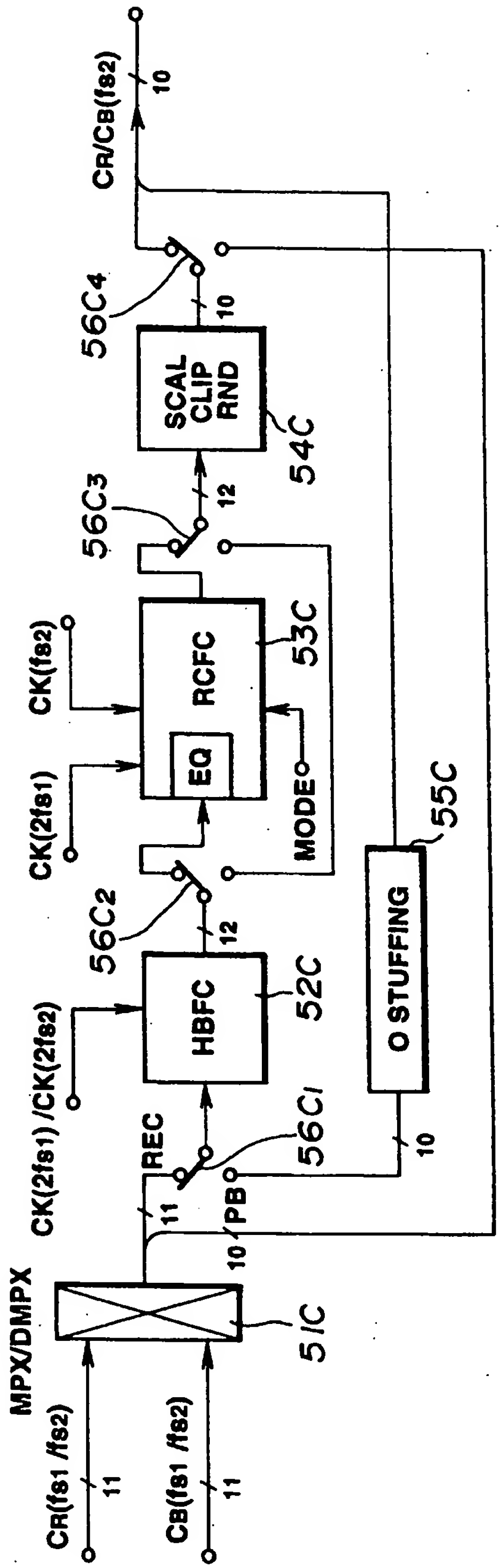

CR/CB(fs2)
10
56C4
SCAL
CLIP
RND
54C
12
56C3
RCFC
EQ
53C
CK(fs2)
CK(2fs1)
MODE
55C
O STUFFING
56C2
HBFC
52C
CK(2fs1) /CK(2fs2)
REC
PB
56C1
11
10
MPX/DMPX
51C
CR(fs1 /fs2)
CB(fs1 /fs2)
11

FIG.8

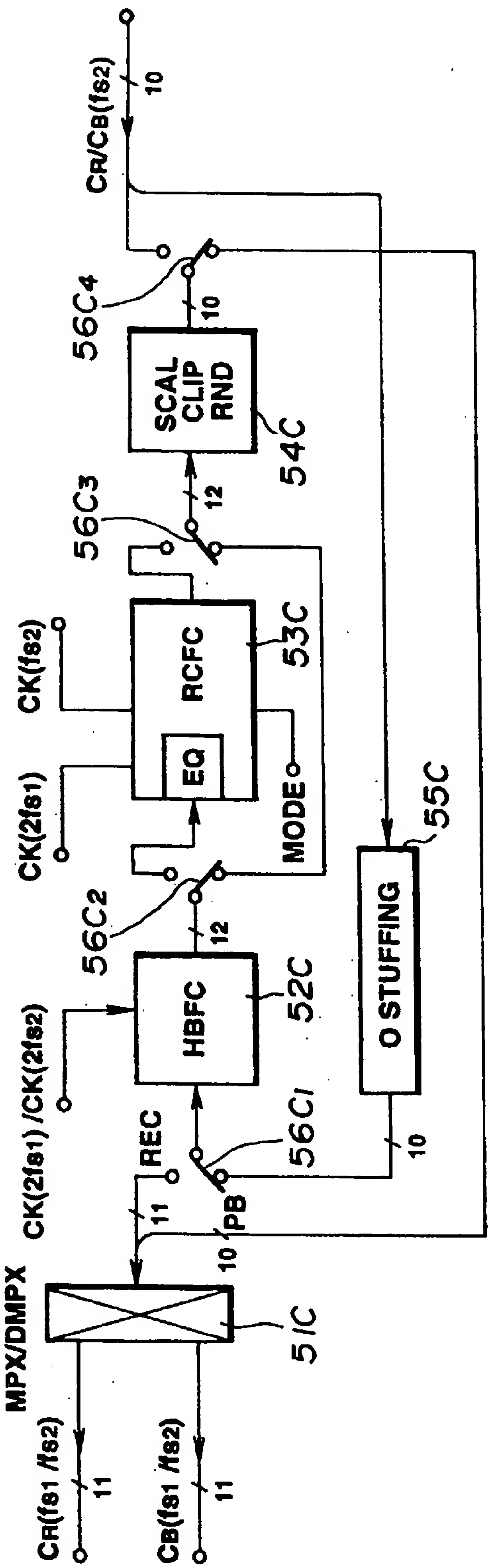

CR/CB(fs2)
10
56C4
10
SCAL
CLIP
RND
54C
56C3
12
CK(fs2)
RCFC
53C
EQ
CK(2fs1)
MODE
56C2
12
HBFC
52C
CK(2fs1) /CK(2fs2)
O STUFFING
55C
REC
56C1
10
11
PB
10
MPX/DMPX
51C
CR(fs1 /fs2)
11
CB(fs1 /fs2)
11

FIG.9

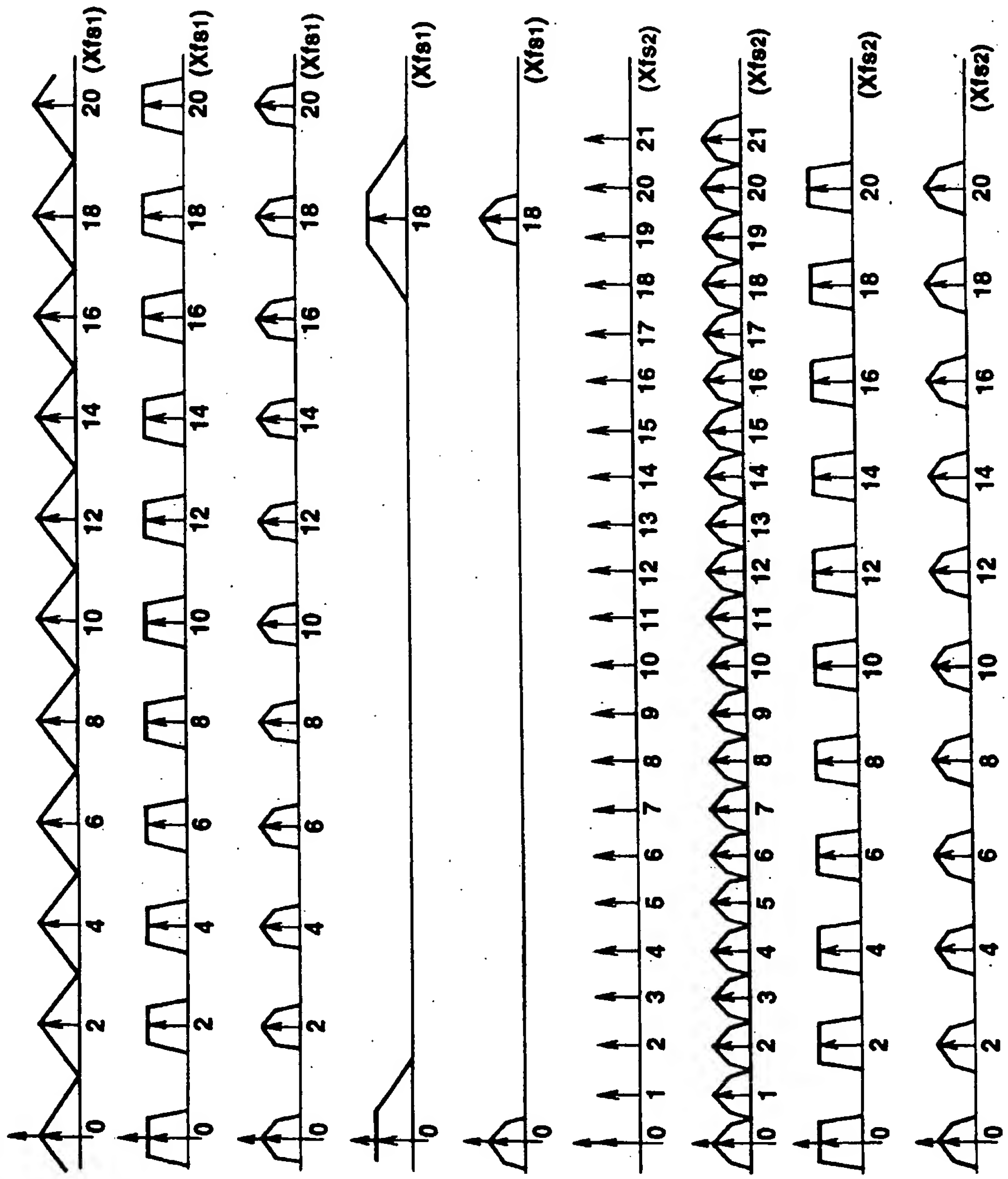


FIG.10(A)

FIG.10(B)

FIG.10(C)

FIG.10(D)

FIG.10(E)

FIG.10(F)

FIG.10(G)

FIG.10(H)

FIG.10(I)

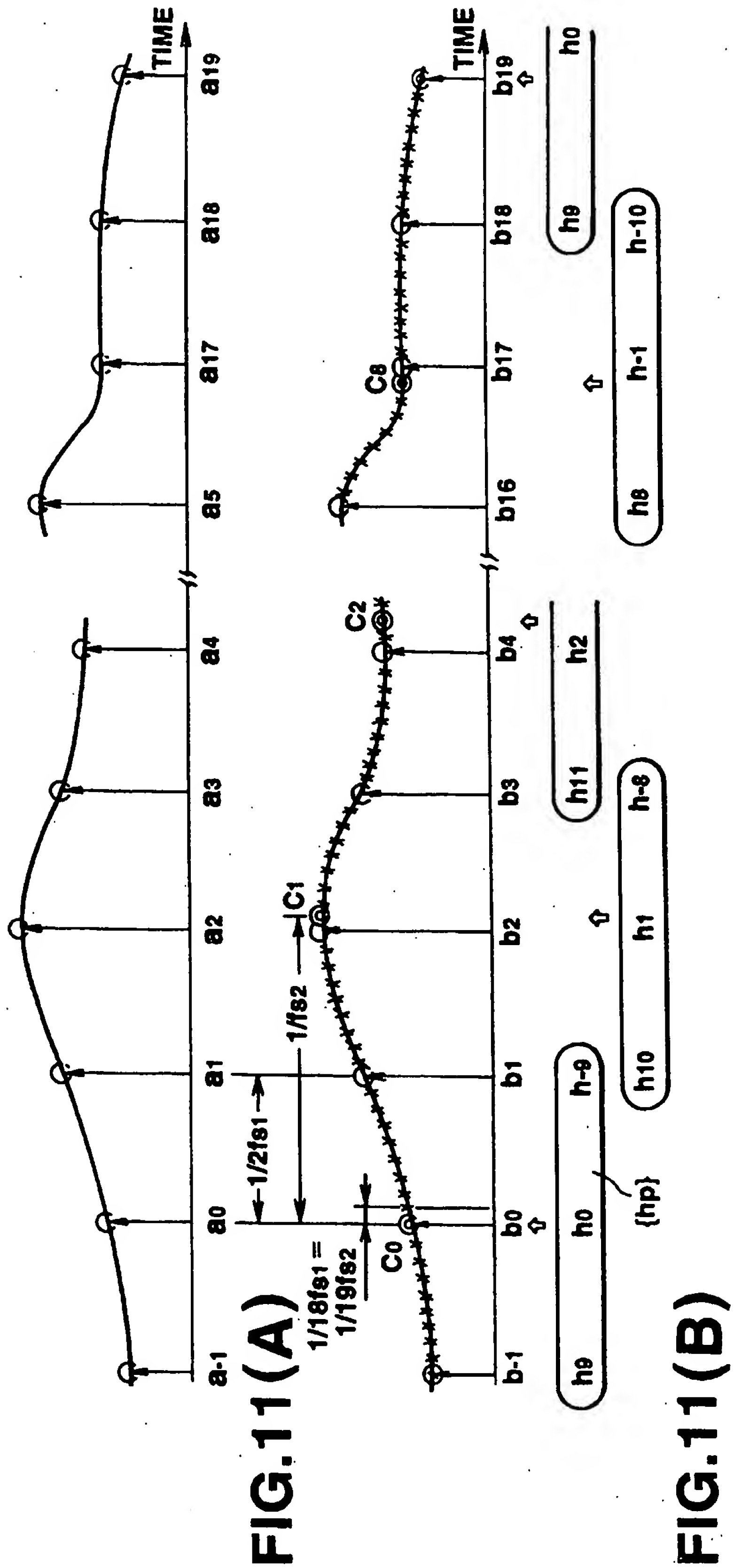
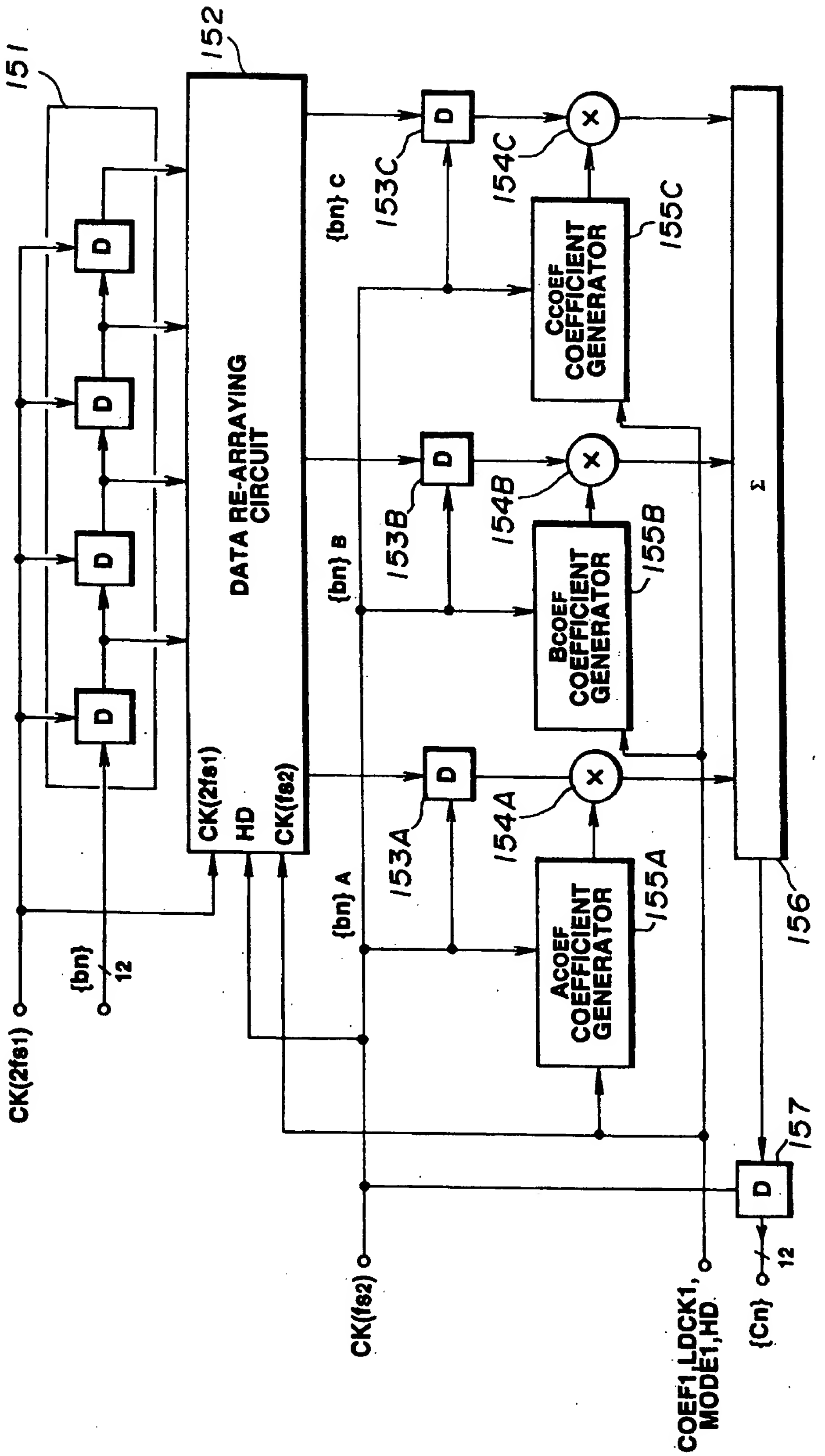


FIG.11(A)

FIG.11(B)



151
152
D
D
D
D
DATA RE-ARRAYING CIRCUIT
CK(2fs1)
HD
CK(fs2)
CK(2fs1)
{bn}
12
{bn} C
{bn} B
{bn} A
153C
153B
153A
154C
154B
154A
155C
155B
155A
CCOEF COEFFICIENT GENERATOR
BCOEF COEFFICIENT GENERATOR
ACOEF COEFFICIENT GENERATOR
Σ
156
157
CK(fs2)
COEF1,LDCK1, MODE1,HD
{Cn}

FIG.12

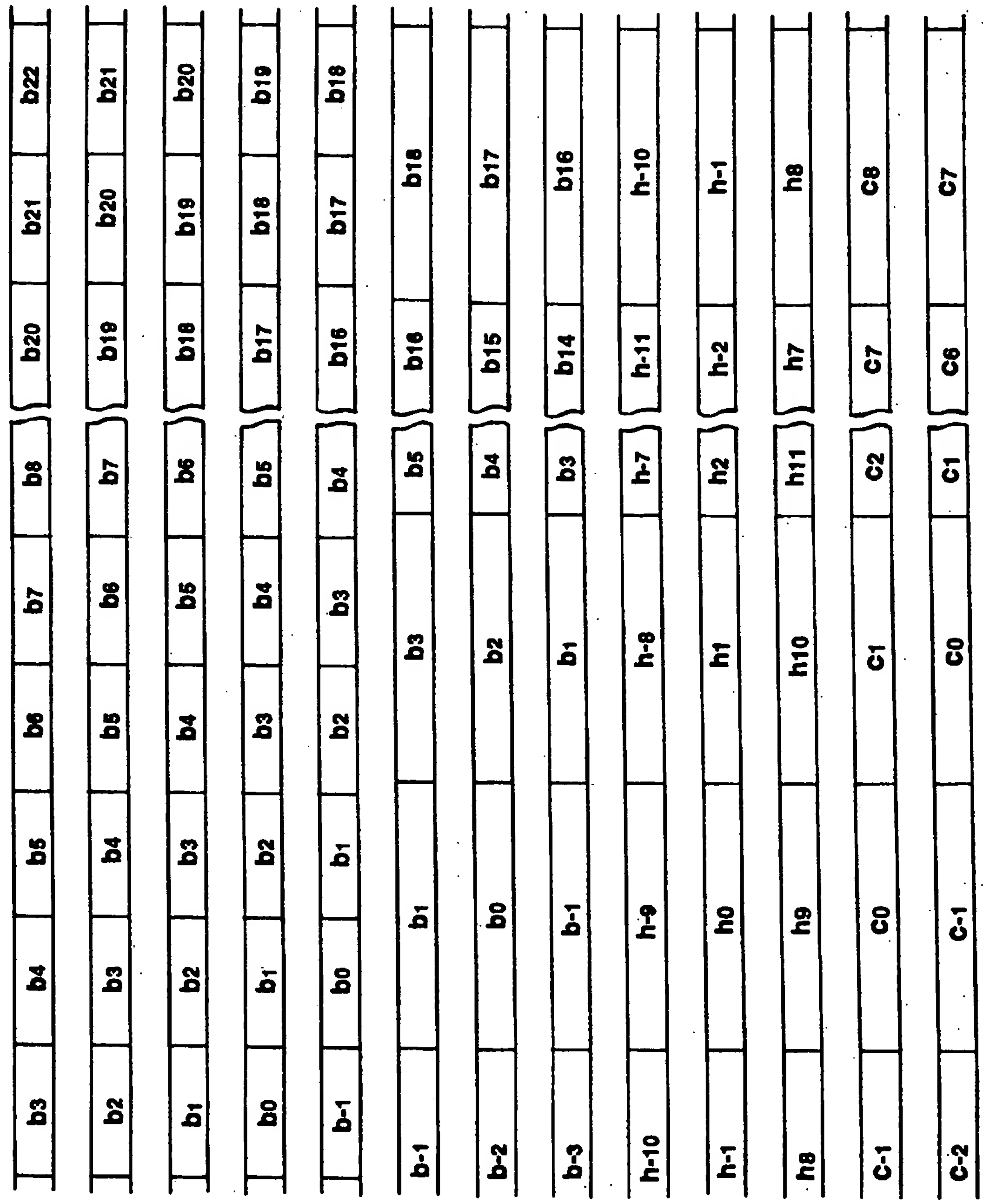


FIG.13 (A)
FIG.13 (B)
FIG.13 (C)
FIG.13 (D)
FIG.13 (E)
FIG.13 (F)
FIG.13 (G)
FIG.13 (H)
FIG.13 (I)
FIG.13 (J)
FIG.13 (K)
FIG.13 (L)
FIG.13 (M)

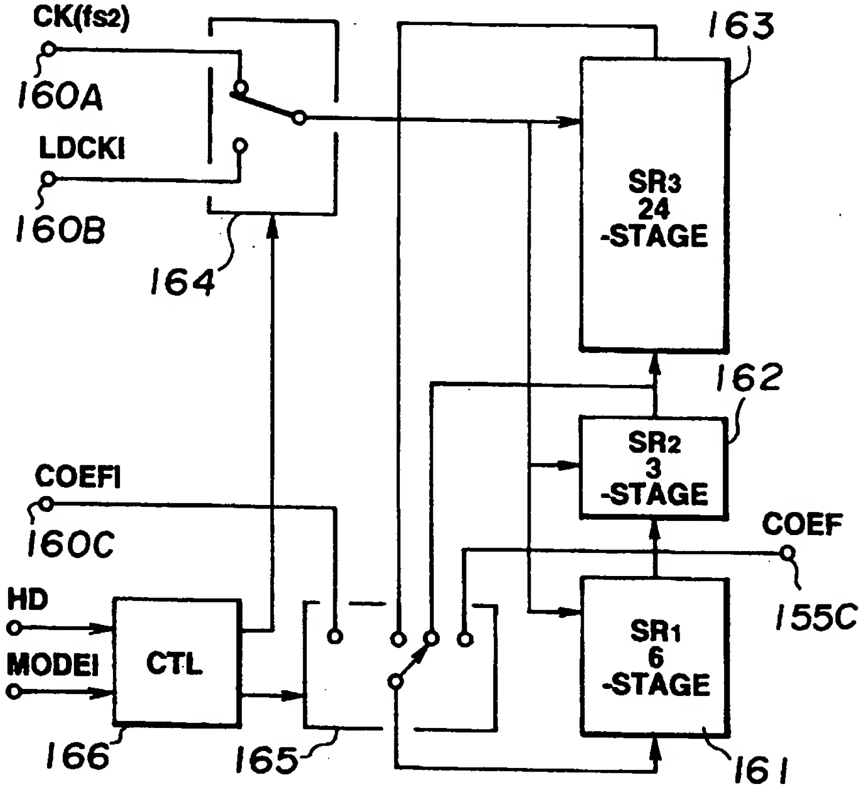

CK(fs2)
160A
LDCKI
160B
164
163
SR3
24
-STAGE
162
SR2
3
-STAGE
COEFI
160C
COEF
155C
HD
MODEI
CTL
SR1
6
-STAGE
166
165
161

FIG.14

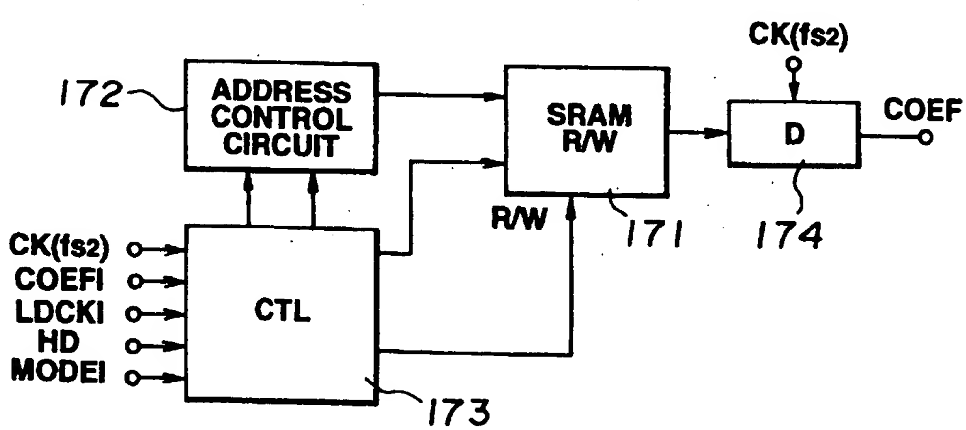

172
ADDRESS
CONTROL
CIRCUIT
SRAM
R/W
CK(fs2)
D
COEF
R/W
171
174
CK(fs2)
COEFI
LDCKI
HD
MODEI
CTL
173

FIG.15

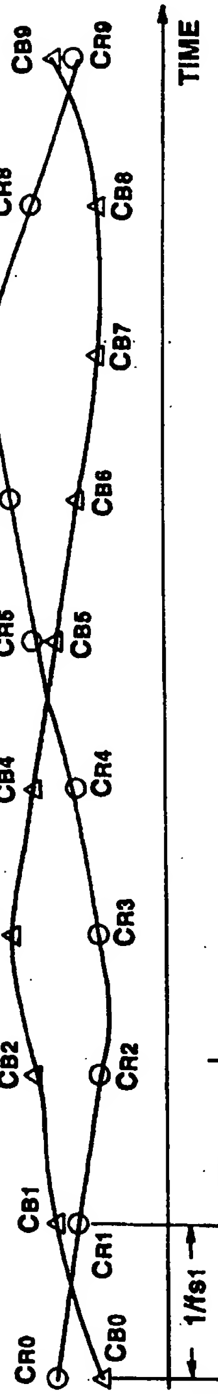


FIG.16(A)

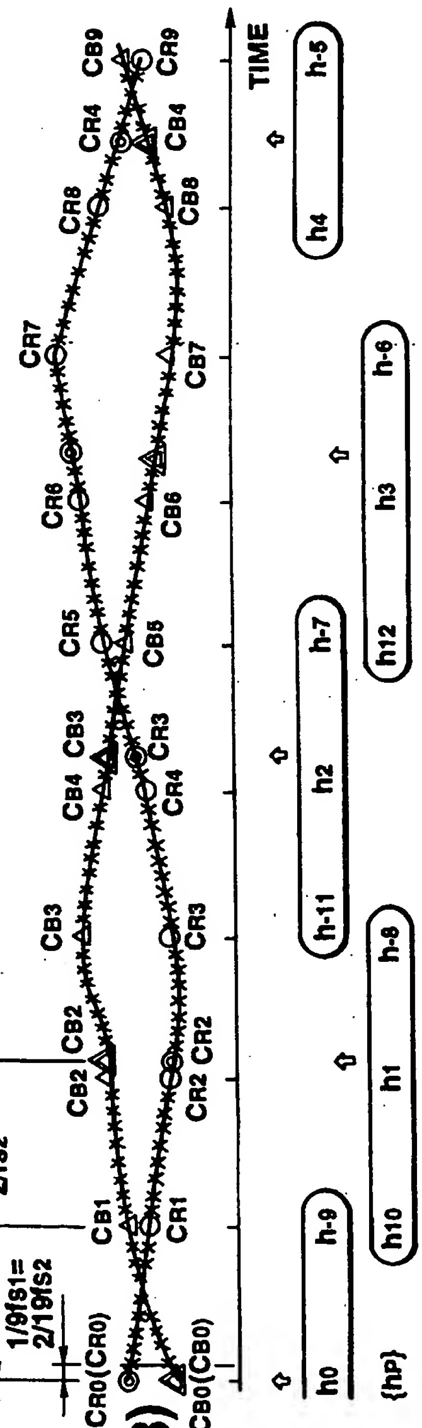


FIG.16(B)

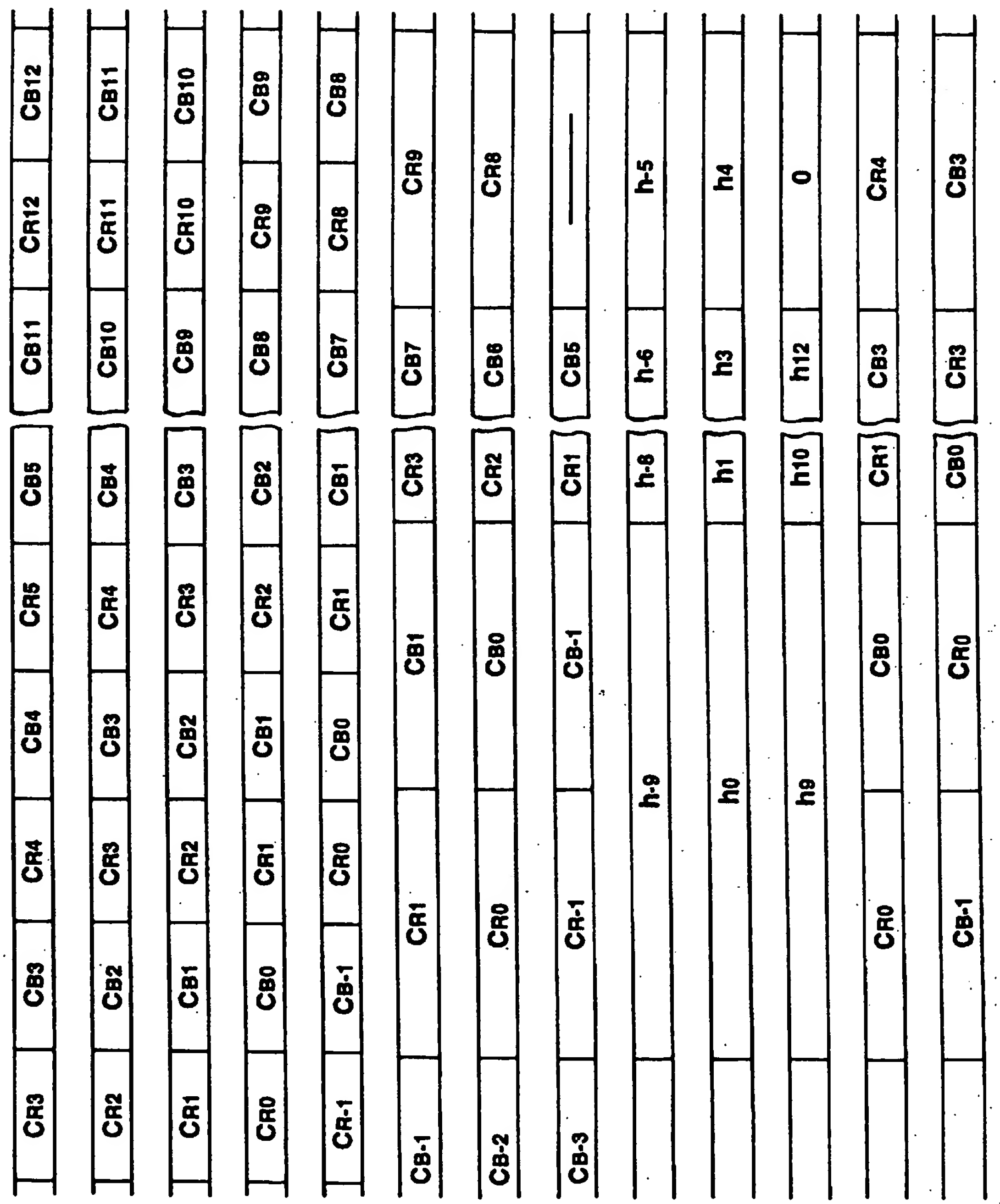
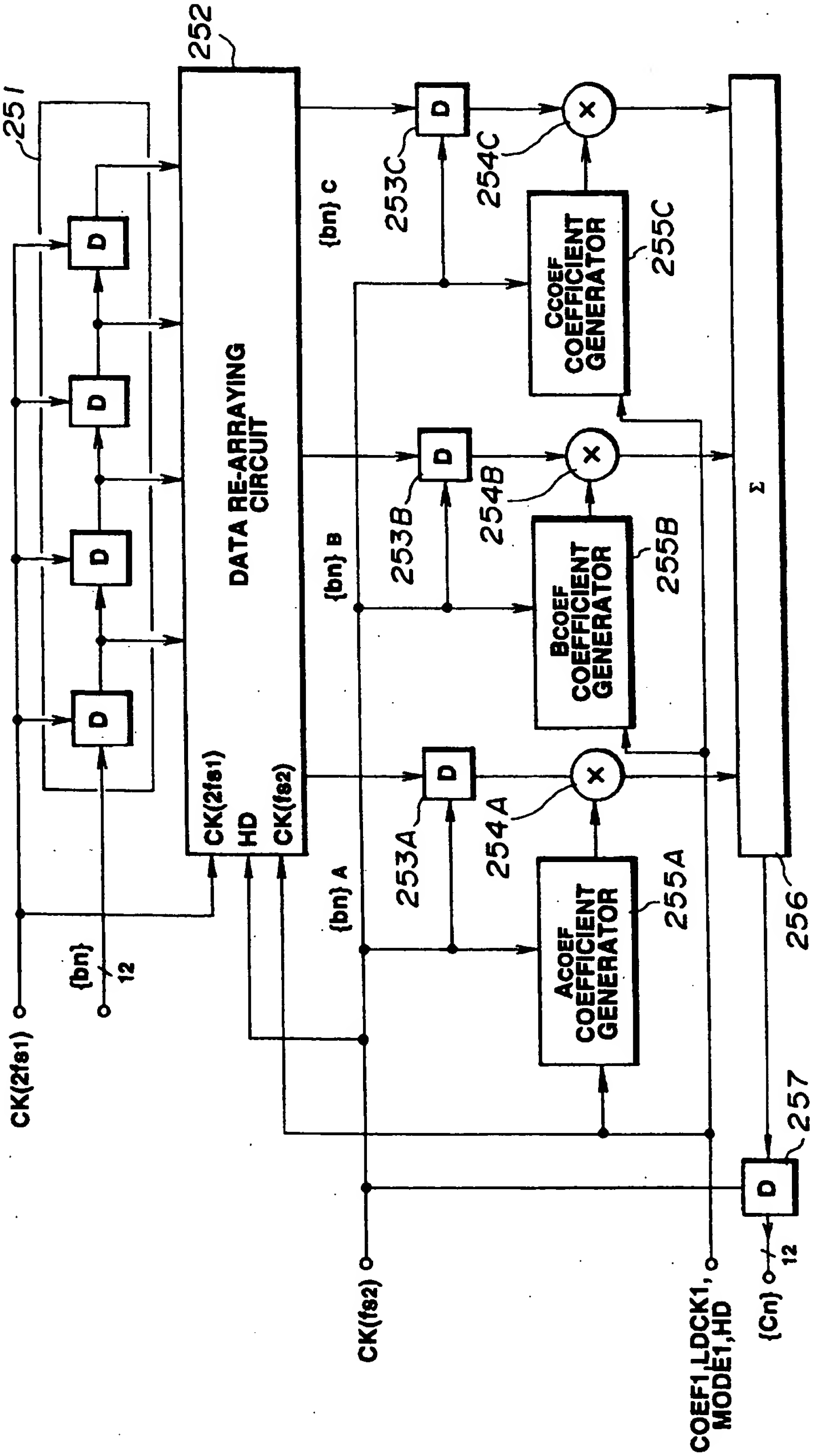


FIG.17(A)
FIG.17(B)
FIG.17(C)
FIG.17(D)
FIG.17(E)
FIG.17(F)
FIG.17(G)
FIG.17(H)
FIG.17(I)
FIG.17(J)
FIG.17(K)
FIG.17(L)
FIG.17(M)



DATA RE-ARRAYING CIRCUIT
CK(2fs1)
HD
CK(fs2)
D
ACOEF COEFFICIENT GENERATOR
BCOEF COEFFICIENT GENERATOR
CCOEF COEFFICIENT GENERATOR
Σ
{bn} A
{bn} B
{bn} C
{bn}
12
{Cn}
COEF1,LDCK1, MODE1,HD
251
252
253A
253B
253C
254A
254B
254C
255A
255B
255C
256
257

FIG.18

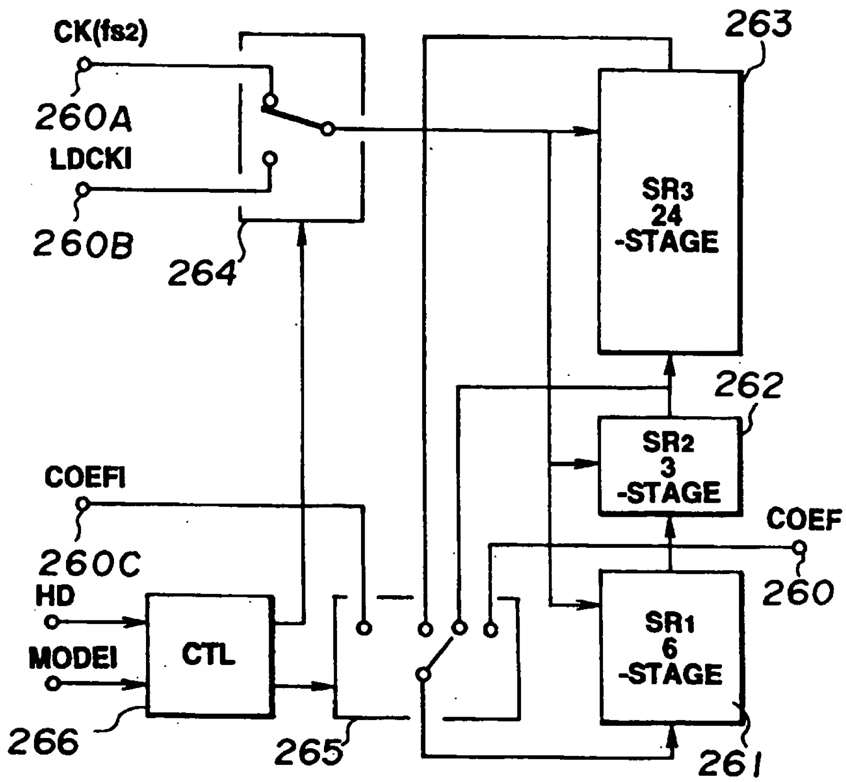

CK(fs2)
260A
LDCKI
260B
264
263
SR3
24
-STAGE
262
SR2
3
-STAGE
COEFI
260C
HD
MODEI
CTL
266
265
COEF
260
SR1
6
-STAGE
261

FIG.19

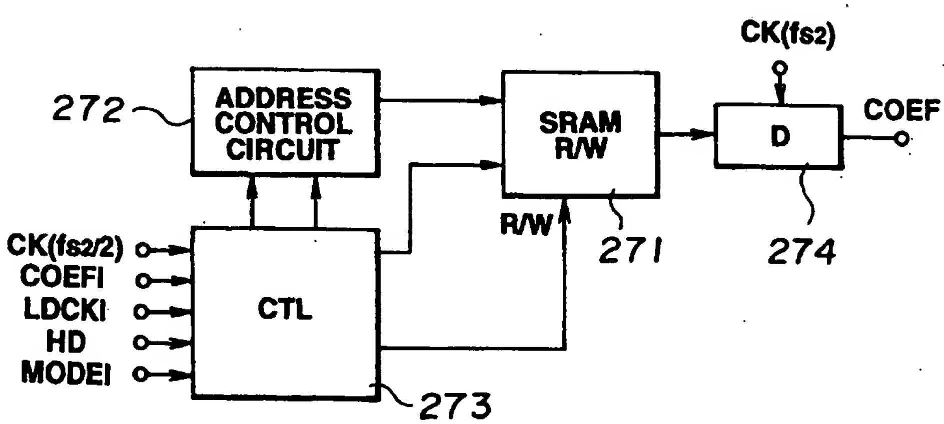

272
ADDRESS
CONTROL
CIRCUIT
SRAM
R/W
CK(fs2)
D
COEF
R/W
271
274
CK(fs2/2)
COEFI
LDCKI
HD
MODEI
CTL
273

FIG.20

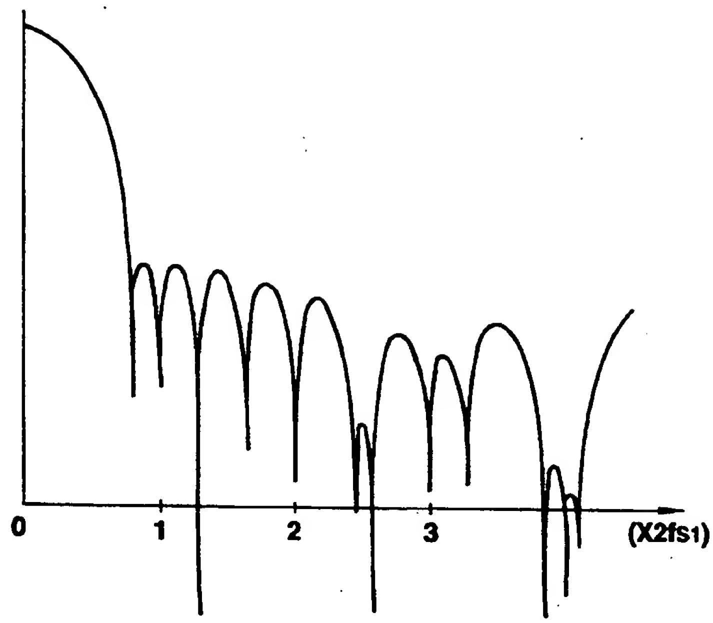

0
1
2
3
(X2fs1)

FIG.21

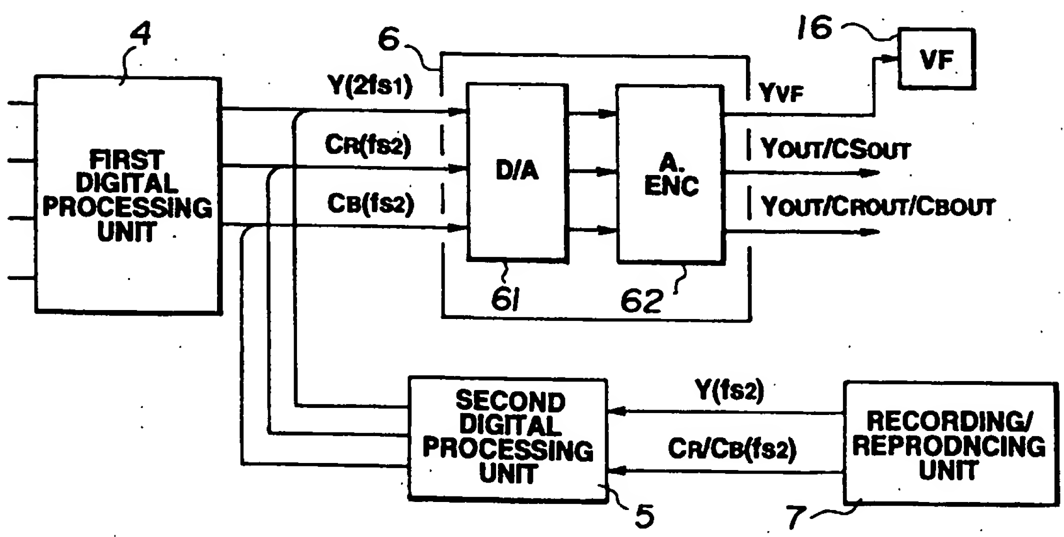

4
FIRST DIGITAL PROCESSING UNIT
6
Y(2fs1)
CR(fs2)
CB(fs2)
D/A
A. ENC
61
62
16
VF
YVF
YOUT/CSOUT
YOUT/CROUT/CBOUT
SECOND DIGITAL PROCESSING UNIT
5
Y(fs2)
CR/CB(fs2)
RECORDING/ REPRODNCING UNIT
7

FIG.23

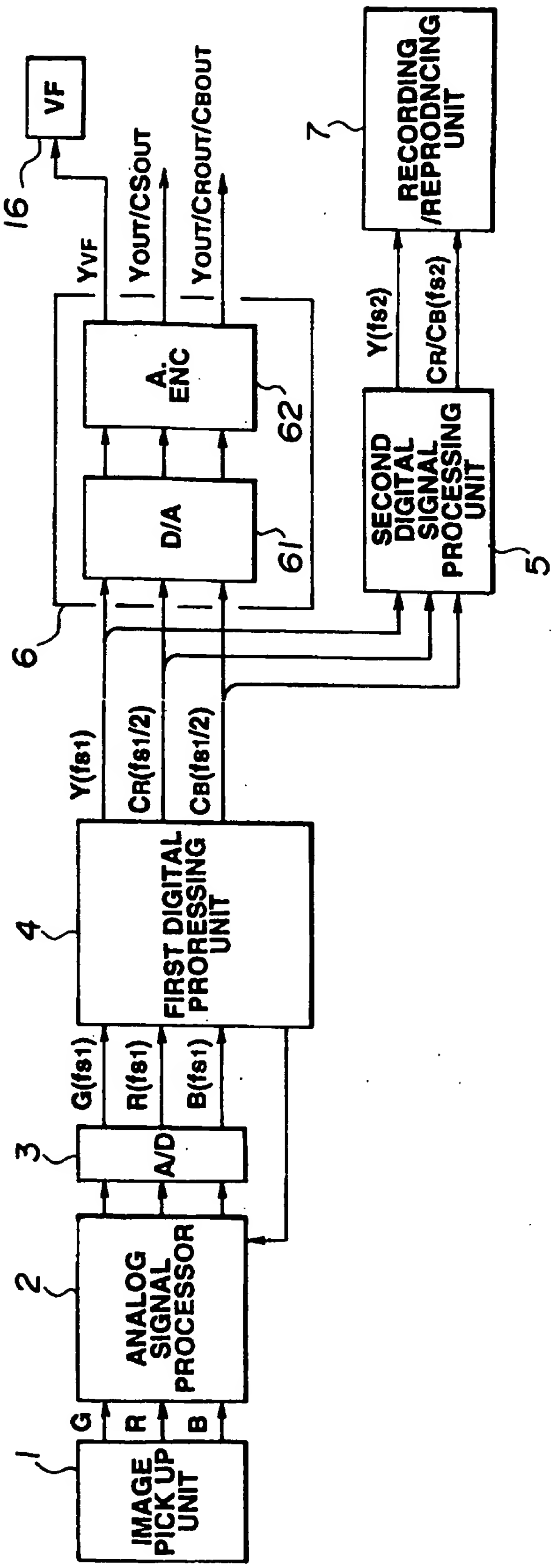

1
IMAGE PICK UP UNIT
G
R
B
2
ANALOG SIGNAL PROCESSOR
3
A/D
G(fs1)
R(fs1)
B(fs1)
4
FIRST DIGITAL PRORESSING UNIT
Y(fs1)
CR(fs1/2)
CB(fs1/2)
6
D/A
61
A. ENC
62
YVF
YOUT/CSOUT
YOUT/CROUT/CBOUT
16
VF
5
SECOND DIGITAL SIGNAL PROCESSING UNIT
Y(fs2)
CR/CB(fs2)
7
RECORDING /REPRODNCING UNIT

FIG.22

SOLID STATE IMAGE PICK-UP APPARATUS FOR CONVERTING THE DATA CLOCK RATE OF THE GENERATED PICTURE DATA SIGNALS

This application is a continuation of application Ser. No. 08/133,296, filed Oct. 8, 1993, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a sol id-state image pickup apparatus for producing digitized picture data from image pickup signals produced by a solid-state image sensor such as a CCD image sensor made up of charge-coupled devices (CCDs) and outputting the produced digitized picture data. More particularly, it relates to a solid-state image pickup apparatus having a rate converting function of converting the data clock rates of the generated picture data.

2. Description of the Prior Art

It is known in general that, in a solid-state image pickup apparatus having, as image pickup means, a solid-state image sensor having a discrete pixel structure, such as a CCD image sensor, since the solid-state image sensor itself is a sampling system, aliasing components from the spatial sampling frequency tend to be mixed into the image pickup signal from the solid-state image sensor. The conventional practice for preventing the generation of aliasing components into the baseband component of the image pickup signals is to provide a double refraction type optical low-pass filter in the image pickup optical system to suppress high-frequency components of the baseband component of the image pickup signals to satisfy the Nyquist conditions of the sampling system constituted by the solid-state image sensor.

On the other hand, with a color television camera device for imaging a color picture, a multiple CCD plate type solid-state image pickup apparatus, such as a two CCD plate type solid-state image pickup apparatus, for imaging a three-color picture by a solid-state image sensor having for imaging a green-colored picture and a solid-state image sensor having a color coding filter for red-colored and blue-colored pictures, or a three CCD plate type solid-state image pickup apparatus for imaging a three-color picture by separate solid-state image sensors, has been put to practical use.

Besides, as a technique for improving the resolution in the above-described multiple CCD plate type solid-state image pickup apparatus, there is known a spatial pixel shifting method in which the solid-state image sensors for imaging red-colored pictures and blue-colored pictures are shifted with respect to the solid-state image sensor for imaging the red-colored picture by one-half the spatial pixel sampling period. By adopting the spatial pixel shifting method, a high resolution exceeding the threshold of the number of pixels of the solid-state image sensor may be realized with the multiple CCD plate type solid-state image pickup apparatus with an analog output.

On the other hand, a D-1 standard or a D-2 standard is prescribed as the standard for an industrial digital VTR employed in e.g. a telecasting station. Thus a digital interface for a digital video related equipment conforming to these standards has become necessary to provide for a color television apparatus.

It is noted that with the D-1 standard for 4:2:2 digital component video signals, the sampling frequency is set to 13.5 MHz, corresponding to 858 times the horizontal frequency $f_{H(NTSC)}$ for the NTSC system and to 864 times the horizontal frequency $f_{H(PAL)}$ for the PAL system, and is adapted for being locked at a frequency equal to an integer number times the horizontal frequency for either systems. On the other hand, with the D-2 standard for the digital composite video signals, the sampling frequency is set to four times the subcarrier frequency to minimize beat interference between the subcarrier and sampling clocks, with the sampling frequency $f_{S(NTSC)}$ for the NTSC system and the sampling frequency for the PAL system $f_{S(PAL)}$ being 14.3 MHz and 17.734 MHz, respectively.

Meanwhile, if it is desired to implement a solid-state image pickup apparatus capable of directly outputting digital picture signals conforming to the above-mentioned D-1 and D-2 standards, such digital picture signals being high in resolution and picture quality and containing only little aliasing distortion components, it is necessary that the sampling rate (number of pixels) of the solid-state image sensor employed in the image pickup unit be set so as to be higher than the sampling rate for the D-1 or D-2 standard, in consideration that the optical low-pass filter as a prefilter for the solid-state image sensor is optically not unobjectionable, that is that only smooth roll-off characteristics may be obtained with the optical low-pass filter such that high modulation transfer function (MTF) characteristics may be obtained only at the costs of increase in the aliasing distortion components.

Besides, if account is taken of the fact that correction of pixel-based defects in the image pickup signals by the solid-state image sensor is performed by a digital technique, and the beat interference has to be prevented from occurring, it is desirable that the sampling rate of the solid-state image sensor be coincident with that of the analog-to-digital converting unit adapted for digitizing the image pickup signals supplied by the solid-state image sensor.

The CCD image sensor now in widespread use is driven at the clock rate of 14.3 MHz=$f_{SC(NTSC)}$. With a digital camera having its image pickup unit constituted by such CCD image sensor, image pickup signals outputted from the solid-state image sensor are digitized at the above-mentioned clock rate of 14.3 MHz=$f_{SC(NTSC)}$ by way of performing a digital signal processing operation.

However, the clock rate in the D-1 standard, which is the standard for the above-mentioned 4:2:2 digital component video signals, cannot be matched to the clock rate for the above-mentioned digital camera having its image pickup unit constituted by such CCD image sensor, with the luminance signal Y and the color difference signals C_R/C_B for the D-1 standard being 13.5 MHz and 6.75 MHz, respectively. If a CCD image sensor having the readout rate of 13.5 MHz is to be fabricated newly for meeting the D-1 standard, there is raised a problem in connection with costs and limitation in general adaptability.

On the other hand, with the multiple CCD plate type solid-state image pickup apparatus, constructed in accordance with the spatial pixel shifting method, the analog output cannot be improved in resolution unless a signal processing system operated at a clock rate of $2f_{s1}$, which is double the clock rate f_{s1} of the CCD image sensor, is employed. Although it may be contemplated to process signals at f_{s1} and $2f_{s1}$ and to turn the signals into analog signals at f_{s1} and $2f_{s1}$, with the analog signals being then passed through an analog filter so as to be digitized again at the clock rate prescribed by the D-1 standard. However, in such case, beat interference is produced between the 14.3

MHz system and the 13.5 MHz system to incur deterioration picture quality.

OBJECTS OF THE INVENTION

In view of the above-depicted status of the art, it is an object of the present invention to provide a solid-state image pickup apparatus wherein digital picture signals with the clock rate of the D-1 standard or other clock rates may be obtained using a standard CCD image sensor.

It is another object of the present invention to provide a solid-slate image pickup apparatus wherein high picture quality digital picture signals free of beat interference may be produced with the aid of a signal processing system operated at the same clock rate as the clock rate for the CCD image sensor.

It is a further object of the present invention to provide a solid-state image pickup apparatus wherein the digital picture signal with a high modulation transfer function (MTF) may be obtained with the use of the spatial pixel shifting method.

It is yet another object of the present invention to provide a solid-state image pickup apparatus which is simplified in construction by simplifying the construction of digital processing means performing a rate converting operation.

SUMMARY OF THE INVENTION

In view of the above objects, the present invention provides a solid-state image pickup apparatus comprising at least one solid-state image sensor driven at a rate f_{s1}, an analog-to-digital converting unit for digitizing picture signals outputted from the solid-state image sensor at the rate f_{s1} of a predetermined phase, a first digital processing unit for generating at least a digital luminance signal Y and two digital color difference signals C_R and C_B from the picture data digitized by the analog to digital converting unit, and a second digital processing unit for converting the input data rate signals Y, C_R and C_B related to the above rate f_{s1} generated by the first digital processing unit into signals Y, C_R and C_B having the output data rate related to the above rate f_{s1}. The second digital processing unit comprises a half band filter having a passband of $f_{s2}/2$, $f_{s2}/4$, $f_{s2}/4$ for performing bandwidth limitation on the input data rate signals Y, C_R and C_B generated by the first digital processing unit, at the output data rates of $2f_{s1}$, f_{s1}, f_{s1}, and a rate converting filter for performing rate conversion of from $2f_{s1}$ to f_{s2}, from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$, from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$, for outputting the low order linear phase finite impulse response sufficient to suppress high-order sideband components in the vicinity of $n\times 2f_{s1}$, $n\times f_{s1}$, $n\times f_{s1}$, n being a positive integer, in a form that can be down-sampled at f_{s2}, $f_{s2}/2$ or $f_{s2}/4$, $f_{s2}/2$ or $f_{s2}/4$, with the half band filter having characteristics of compensating bandpass roll-off characteristics of the rate converting filter.

With the solid-state image pickup apparatus according to the present invention, the rate converting filter has at least one zero point at $n\times 2f_{s1}$, $n\times f_{s1}$, $n\times f_{s1}$ and each two zero points in the vicinity thereof.

With the solid-state image pickup apparatus according to the present invention, the rate converting filter is constituted by a plurality of multipliers.

With the solid-state image pickup apparatus according to the present invention, the half band filter comprises a product of partial filters each constituted by integer coefficients.

The present invention also provides a solid-state image pickup apparatus comprising a plurality of solid-state image sensors arranged in a color-separating system in accordance with the spatial pixel shifting method so as to be driven at a predetermined rate of f_{s1}, analog-to-digital converting means coupled to the image sensors for digitizing the image signals at a rate of f_{s1}, first digital processing means supplied with the image signals digitized by the analog-to-digital converting means for providing at least a digital luminance signal Y ($2f_{s1}$) having a rate equal to $2f_{s1}$ and two digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) each having a rate equal to f_{s1}, second digital processing means coupled to the first digital processing means for converting the data rate of the input data rate signals Y ($2f_{s1}$), C_R (f_{s1}), C_B (f_{s1}) from m to n, m and n being natural numbers, for providing a digital luminance signal Y(f_{s2}) having a rate equal to $f_{s2}=2f_{s1}\cdot n/m$ and two color difference signals C_R (f_{s2}) and C_B (f_{s2}) having a rate substantially equal to $f_{s2}/2$.

The second digital processing unit in the solid-state image pickup apparatus according to the present invention comprises a half band filter having a passband of f_{s2}, $f_{s2}/2$ and $f_{s2}/2$ for the input data rate signals Y ($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}), respectively, generated by the first digital processing unit at output data rates of $2f_{s1}$, f_{s1} and f_{s1}, respectively, and a rate converting filter for performing suppression of high-order side-band components in the vicinity of $n\times 2f_{s1}$, $n\times f_{s1}$ and $n\times f_{s1}$, respectively, on signals Y ($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}) supplied via the half band filter in the down-sampled form of f_{s2}, $f_{s2}/2$ and $f_{s2}/2$, respectively, n being a natural number.

The solid-state image pickup device digitizes image pickup (picture) signals outputted from at least a solid-state image sensor driven at a rate f_{s1}, at a rate f_{s1} with a predetermined phase by a predetermined analog-to-digital converting unit to form digital image pickup data, generates a digital luminance signal Y and two digital chrominance signals C_R, C_B from the digital image pickup data by a first digital processing unit operated at a clock rate related to the rate f_{s1}, and converts the signals Y, C_R and C_B having an input data rate related to the f_{s1} rate into signals Y, C_R and C_B having an output data rate related to the f_{s2} rate by a second digital processing unit. The second digital processing unit performs bandwidth limitation on the input data rate signals Y, C_R and C_B, generated by the first signal processor, at output data rates of $2f_{s1}$, f_{s1} and f_{s1}, by a half band filter having a passband of $f_{s2}/2$, $f_{s2}/4$ and $f_{s2}/4$, respectively, and performs rate conversion of from $2f_{s1}$ to f_{s2}, from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$, from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$, for outputting the low order linear phase finite impulse response sufficient to suppress high-order sideband components in the vicinity of $n\times 2f_{s1}$, $n\times f_{s1}$, $n\times f_{s1}$, n being a positive integer, in a form that can be down-sampled at f_{s2}, $f_{s2}/2$ or $f_{s2}/4$, $f_{s2}/2$ or $f_{s2}/4$, respectively. Besides, the bandpass roll-off characteristics of the rate converting filter may be compensated by the characteristics of the half band filter.

With the solid-state image pickup apparatus according to the present invention, the signal limited in bandwidth by the half band filter is rate-converted by a rate converting filter having an integer coefficient impulse response having at least one zero point at $n\times 2f_{s1}$, $n\times f_{s1}$ and $n\times f_{s1}$ and each two zero points in the vicinity thereof.

With the solid-state image pickup apparatus according to the present invention, the signals limited in bandwidth by the half band filter are rate-converted by a rate converting filter.

With the solid-state image pickup apparatus according to the present invention, the input data rate signals Y, C_R and

C_B generated by the first digital processing unit, are limited in bandwidth by a half band filter comprising a product of partial filters each constituted by integer coefficients.

Besides, with the solid-state image pickup apparatus according to the present invention, output image pickup signals of plural solid-state image sensors arranged in the color-separation optical system in accordance with the spatial pixel shifting method so as to be driven at the rate f_{s1} are digitized by the analog-to-digital converting unit at the rate f_{s1} having a predetermined phase, at least a $2f_{s1}$ rate digital luminance signals Y $(2f_{s1})$ and two f_{s1} rate digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) are generated by the first digital processing unit from the digitized image pickup data and rate-converted by the second digital processing unit from m to n, m and n being positive integers, for generating digital luminance signals Y (f_{s2}) having the rate of $f_{s2}=f_{s1}\cdot n/m$ and digital color difference signals C_R (f_{s2}) and C_B (f_{s2}) C_B having substantially the data rate of $f_{s2}/2$.

On the other hand, with the solid-state image pickup apparatus according to the present invention, the second digital processing unit performs bandwidth limitation on the input rate signals Y $(2f_{s1})$, C_R (f_{s1}) and C_B (f_{s1}) generated by the first digital processing unit at the output rates of $2f_{s1}$, f_{s1} and f_{s1}, by a half band filter having a passband of $f_{s2}/2$, $f_{s2}/4$ and $f_{s2}/4$, respectively, and generates digital color difference signals C_R (f_{s2}), C_B (f_{s2}) C_B having substantially the rate of $f_{s2}/2$.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing an arrangement of a digital cam corder embodying the present invention.

FIG. 2 is a block diagram showing an illustrative example of a signal processing section for an analog output in the digital cam corder shown in FIG. 1.

FIG. 3 is a block diagram showing another illustrative example of a signal processing section for an analog output in the digital cam corder shown in FIG. 1.

FIG. 4 is a block diagram showing an illustrative example of a rate converting circuit for luminance signals in the digital cam corder shown in FIG. 1.

FIG. 5 is a block diagram showing the state of connection for a recording mode of the rate converting circuit for luminance signals.

FIG. 6 is a block diagram showing the state of connection for a playback mode of the rate converting circuit for luminance signals.

FIG. 7 is a block diagram showing an illustrative example of a rate converting circuit for color difference signals in the digital cam corder shown in FIG. 1.

FIG. 8 is a block diagram showing the state of connection for a recording mode of the rate converting circuit for color difference signals.

FIG. 9 is a block diagram showing the state of connection for a playback mode of the rate converting circuit for color difference signals.

FIG. 10*a–i* is a spectral diagram for illustrating the operation of the rate converting circuit for luminance signals.

FIG. 11*a–b* is a timing chart for illustrating the operation of the rate converting circuit for luminance signals.

FIG. 12 is a block circuit diagram for illustrating an illustrative construction of a rate converting filter in the rate converting circuit for luminance signals.

FIG. 13*a–m* is a timing chart for illustrating the operation of the rate converting filter for luminance signals.

FIG. 14 is a block circuit diagram for illustrating an illustrative construction of a coefficient generator in the rate conversion filter for luminance signals.

FIG. 15 is a block circuit diagram for illustrating another illustrative construction of a coefficient generator in the rate conversion filter for luminance signals.

FIG. 16*a–b* is a timing chart for illustrating the operation of the rate converting circuit for color difference signals.

FIG. 17*a–m* is a timing chart for illustrating the operation of the rate converting filter for color difference signals.

FIG. 18 is a block circuit diagram for illustrating an illustrative construction of the rate converting filter in the rate converting circuit for color difference signals.

FIG. 19 is a block circuit diagram for illustrating an illustrative construction of a coefficient generator in the rate conversion filter for color difference signals.

FIG. 20 is a block circuit diagram for illustrating another illustrative construction of a coefficient generator in the rate conversion filter for color difference signals.

FIG. 21 is a graph showing a concrete example of the characteristics of the rate converting filter for luminance signals.

FIG. 22 is a block diagram showing the operating state of essential parts for the recording mode of the digital cam corder.

FIG. 23 is a block circuit diagram showing the operating state of essential parts for the playback mode of the digital cam corder.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, certain preferred embodiments of the present invention will be explained in detail.

The solid state image pickup apparatus is arranged as shown for example in FIG. 1.

The solid-state imaging device according to the fi rat embodiment shown in FIG. 1 is a digital cam corder in which imaging signals produced by an image pickup unit 1 are digitized so as to be recorded as picture data conforming to the D1 standard. The solid-state image pickup apparatus includes an analog-to-digital converting unit 3 to which three-color image pickup signals R, G and B produced by the image pick-up unit 1 are supplied via an analog signal processing unit 2, a first digital processing unit 4 to which the color image pick-up data digitized by the A/D converting unit 3 are supplied, a second digital processing unit 5 to which a digital luminance signal Y and two digital color difference signals C_R, C_B generated by the first digital processing unit 4 are supplied, and a signal processing unit for an analog output 6. A recording/reproducing unit 7 for recording and reproducing picture data conforming to the D1 standard is connected to the second digital processing unit 5.

The color image pickup unit 1 is made up of three CCD plate type CCD image sensors 1R, 1G and 1B for separating an image pickup light incident thereto from an image pickup lens, not shown, via an optical low-pass filter into three color light components by a color-separating prism, not shown, for forming a three-color picture of an object image.

In the present embodiment, the three CCD image sensors 1R, 1G and 1B are arrayed in accordance with a spatial pixel shifting method in which the red-color image pickup CCD

image sensor 1R and the blue-color image pickup CCD image sensor 1B are arrayed with a spatial shift of one-half the spatial sampling period τ_s with respect to the green-color image pickup CCD image sensor 1G.

Meanwhile, the present invention may be applied not only to the three CCD plate type solid-state image pickup apparatus constructed in accordance with the spatial pixel shifting method of the present embodiment, but may also be applied to a single CCD or double CCD plate type solid-state image pickup apparatus or to a three CCD plate type solid-state image pickup apparatus not constructed in accordance with the spatial pixel shifting method.

Each of the three CCD image sensors 1R, 1G and 1B is driven at an f_{s1} rate by a driving clock CK(f_{s1}) generated by a timing generator (TG) 9 on the basis of a $2f_{s1}$ rate clock supplied from a voltage controlled oscillator (VCO) 8.

The number of pixels of each of the three CCD image sensors 1R, 1G and 1B is selected so that the image pickup charges are read out at a rate of f_{s1}=910 f_H for EIA and at a rate of f_{s1}= 912 f_H for CCIR. The oscillation frequency of VCO 8 is set to $2f_{s1}$, while the timing generator 9 is adapted for driving the three CCD image sensors 1R, 1G and 1B by the f_{s1} rate driving clocks CK (f_{s1}) obtained by halving the frequency of the clock CK ($2f_{s1}$).

The respective color image pickup signals R(f_{s1}), G(f_{s1}) and B(f_{s1}), read out at the f_{s1} rate from the CCD image sensors 1R, 1G and 1B, respectively, are supplied to the analog signal processing unit 2.

The analog signal processing unit 2 is made up of a correlated double sampling processing circuits (CDS processing circuits) 21R, 21G and 21B, and level controlling circuits 22R, 22G and 22B. The CDS processing circuits 21R, 21G and 21B perform correlated double sampling on the color image pickup signals R, G and B, read out from the CCD image sensors 1R, 1G and 1B at the f_{s1} rate, respectively. Besides, the level controlling circuits 22R, 22G and 22B perform level control, such as white balance or black balance control, on %he color image pickup signals R, G and B, respectively.

The A/D converter 3, supplied via the analog signal processor 2 with the respective color pickup signals R(f_{s1}), G(f_{s1}) and B(f_{s1}), produced by the image-pickup unit 1, is made up of three A/D converters 3R, 3G and 3B, each having a word length of 10 bits. These A/D converters 3R, 3G and 3B are supplied from the timing generator 9 with the driving clocks Ck (f_{s1}) having a predetermined phase and a rate f_{s1} equal to the sampling rate of each of the respective color image pickup signals R(f_{s1}), G(f_{s1}) and B(f_{s1}). The A/D converters 3R, 3G and 3B of the A/D converting unit 3 digitize the respective color signals R(f_{s1}), G(f_{s1}) and B(f_{s1}) at the rate equal to f_{s1} by the above-mentioned driving clocks CK(f_{s1}), for forming respective digital color signals R(f_{s1}), G(f_{s1}) and B(f_{s1}), having the same signal spectrum as the spectrum of each of the respective color signals R(f_{s1}), G(f_{s1}) and B(f_{s1}), respectively.

Meanwhile, the A/D converters 3R, 3G and 3B may also be designed to have a word length on the order of 12 to 14 bits.

The respective color signals R(f_{s1}), G(f_{s1}) and B(f_{s1}), with the rate equal to f_{s1}, digitized by the A/D converting unit 3, are supplied to the first digital processing unit 4.

The first digital processing unit 4 is made up of a first digital processing circuit 41 and a second digital processing circuit 42.

The first digital processing circuit 41 is activated at the rate equal to f_{s1} by the driving clocks CK (f_{s1}) supplied from the timing generator 9 for detecting a variety of correcting signal levels of the respective digital color signals R(f_{s1}), G(f_{s1}) and B(f_{s1}) supplied from the A/D converting unit 3 for storing e.g. white balance controlling data, black balance controlling data, black shading correction data, white shading correction data or defect correction data in a memory 43, converting the respective color signals into analog signals by D/A converters 44R, 44G and 44B, and feeding back the analog color signals to the level controlling circuits 22R, 22G and 22B of the analog signal processing unit 2, respectively, for performing white/black balance control, shading correction or defect correction.

Meanwhile, the memory 43 is an SRAM connected to a battery 45 as a backup power source.

Thus, in the present embodiment, the respective color pickup signals R(f_{s1}), G(f_{s1}) and B(f_{s1}), read out at the rate equal to f_{s1} from the respective CCD image sensors 1R, 1G and 1B, are digitized by the A/D converting unit 3 for producing the respective color image pickup signals R(f_{s1}), G(f_{s1}) and B(f_{s1}), respectively, so that the first digital processing circuit 41 may be activated at the rate equal to f_{s1} for performing pixel-based picture processing, such as shading correction or defect correction.

On the other hand, the second digital processing circuit 42 performs picture enhancement, pedestal addition, non-linear processing, such as gamma or knee processing or linear matrix processing, on the respective color image pickup signals R, G and B, processed with the pixel-based processing by the first digital processing circuit 41. Besides, the second digital processing circuit 42 generates, by the matrix processing, a digital luminance signal Y ($2f_{s1}$) and two digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) from the respective color image pickup signals R(f_{s1}), G(f_{s1}) and B(f_{s1}).

It is noted that the second digital processing circuit 42, supplied with the clocks CK ($2f_{s1}$), having the rate equal to $2f_{s1}$, from the VCO 8, and with the driving clocks CK (f_{s1}), having the rate equal to f_{s1}, from the timing generator 9, is activated with these clocks CK ($2f_{s1}$) and CK (f_{s1}) as master clocks for performing well-known high resolution processing corresponding to the spatial pixel shifting method in the image pickup unit 1 for generating the digital luminance signal Y ($2f_{s1}$) having the rate equal to $2f_{s1}$ and the two digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) each having the rate equal to f_{s1}.

Meanwhile, the master clocks CK ($2f_{s1}$) and CK (f_{s1}) are also supplied to a synchronizing signal generator (SG) 11 for generating various synchronizing signals, such as horizontal synchronizing signals HD or vertical synchronizing signals VD.

On the other hand, the second digital processing unit 5 performs bidirectional rate conversion between signals having the data rate related to the rate f_{s1} and signals having the data rate related to the rate f_{s2}. For the recording mode, the second digital processing unit 5 converts the signals Y ($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}), related to the rate f_{s1}, generated by the first digital processing unit 4, into signals Y (f_{s2}), C_R (f_{s2}/2) and C_B (f_{s2}/2), related to the rate f_{s2}, for supplying the converted data to the recording/reproducing unit 7. For the playback mode, the second digital processing unit 5 converts the signals Y (f_{s2}), C_R (f_{s2}/2) and C_B (f_{s2}/2), related to the rate f_{s2}, into signals Y ($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}), related to the rate f_{s1}, for supplying the converted data to the signal processing unit for analog output 6.

The second digital processing unit 5 is made up of a rate converting circuit 50Y for the luminance signal and a rate converting circuit 50C for the color difference signals.

A digital interface 13 for external equipment is provided between the second digital processing unit 5 and the recording/reproducing unit 7. For an external input mode, the second digital processing unit 5 converts digital return signals Y (f_{s2}), C_R ($f_{s2}/2$) and C_B ($f_{s2}/2$), related to the rate f_{s2}, entered from a digital camera control unit (D-CCU) 14 via a camera adapter D-CA 15, into signals Y ($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}), having the rate f_{s1}, for supplying the converted signals to the signal processing unit for analog output 6.

In the present embodiment, the signal processing unit for analog output 6 plays the role of an analog interface for the signals Y ($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}), related to the rate f_{s1}, generated by the first digital processing unit 4 or the second digital processing unit 5, and is made up of a digital/analog (D/A) converting unit 61 and an analog encoder 62.

The D/A converting unit 61 is made up of three D/A converters 61Y, $61C_R$ and $61C_B$ and three post-filters 61PFY, $61PFC_R$ and $61PFC_B$.

In the D/A converting unit 61, the digital luminance signal Y ($2f_{s1}$), having the data rate equal to $2f_{s1}$, is converted into an analog signal, which is then freed of a sampling carrier component by the post-filter 61Y playing the role of a Nyquist filter, before being supplied to the analog encoder 62. On the other hand, the two digital color difference signals C_R (f_{s1}) and C_B (f_{s1}), having the rate equal to f_{s1}, are converted by the D/A converters $61C_R$ and $61C_B$ into analog signals, which then are freed of sampling carrier components by the post-filters $61PFC_R$ and $61PFC_B$ playing the role of a Nyquist filter, before being supplied to the analog encoder 62.

The analog encoder 62 is an encoder conforming to the usual NTSC OF PAL and is adapted for outputting component signals Y, C_R and C_B and a composite signal CS as well as for outputting a monitor signal Y_{VF} to be supplied to a view finder

The analog encoder 62 is constructed as shown for example in FIG. 2.

In the analog encoder 62, the two analog color difference signals C_R and C_B, supplied from the D/A converting unit 61, are bandwidth-limited to a predetermined bandwidth, with fc being approximately equal to 1 MHz, by low-pass filters $63C_R$ and $63C_B$, and added to by a burst flag BF by signal synthesizers $64C_R$ and $64C_B$ before being supplied to a modulator 65. The modulator 65 modulates a quadrature 2-phase subcarrier SC by the analog color difference signals C_R and C_B for generating a modulated chroma signal C_{OUT}.

On the other hand, the analog luminance signal Y, supplied by the D/A converter 61, is compensated for delay caused by the low-pass filters $63C_R$ and $63C_B$ by a delay circuit 66, and subsequently added to by a synchronizing signal and a setup signal by signal synthesizer 67 to form a prescribed luminance signal Y_{OUT}. The luminance signal Y_{OUT}, produced in this manner, is improved in resolution by digital processing corresponding to the above-mentioned spatial pixel shifting method, while containing only little aliasing distortion components.

The luminance signal Y_{OUT} and the above-mentioned modulated chroma signal C_{OUT} are mixed by a signal mixer for generating a composite signal CS_{OUT}.

On the other hand, the luminance signal Y_{OUT} is mixed with character signals from a character generator 69 by a signal mixer 70 and subsequently the mixed signal is outputted via a changeover circuit 71 as a monitoring signal Y_{VF}. The changeover circuit 71 performs switching between a return signal RET entered from outside and the above-mentioned luminance signal Y_{OUT}.

The signal processing unit for analog output 6 may also be so designed that a digital encoder 73, as shown in FIG. 3, by a third digital processing unit operated with a clock rate related with the rate equal to f_{s1} is employed in place of the analog encoder 62. The digital luminance signal Y_{OUT}, digital composite signal CS_{OUT} and the digital monitoring signal Y_{VF}, outputted by the digital encoder 73, may be converted into analog signals by D/A converter 74Y, 74CS and $75Y_{VF}$ so as to be outputted via post-filters 74PFY, $74PFC_S$ and $75PFY_{VF}$.

With the present embodiment, the second digital processing unit 5 performs bidirectional rate conversion between signals having a data rate related to the rate of f_{s1} and signal s having a data rate related to the rate of f_{s2} and, as a principle, performs conversion from the digital luminance signal Y ($2f_{s1}$), having the data rate equal to $2f_{s1}$, into the digital luminance signal Y (f_{s2}), having the data rate equal to f_{s2} and from the digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) having the rate equal to f_{s1} into digital color difference signals C_R ($f_{s2}/2$) and C_B ($f_{s2}/2$) having the rate equal to $f_{s2}/2$, for the recording mode. The second digital processing circuit 5 performs conversion from the digital luminance signal Y (f_{s2}), having the data rate equal to f_{s2}, into the digital luminance signal Y ($2f_{s1}$), having the data rate equal to $2f_{s1}$, and from the digital color difference signals C_R ($f_{s2}/2$) and C_B ($f_{s2}/2$) having the rate equal to $f_{s2}/2$ into digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) having the rate equal to f_{s1}, for the playback mode. For simplifying the construction of the rate conversion circuits 5OY, 50C, the digital luminance signal Y (f_{s2}), having the data rate equal to f_{s2}, are converted into the digital luminance signal Y ($2f_{s2}$) , having the data rate equal to $2f_{s2}$, while the digital color difference signals C_R ($f_{s2}/2$) and C_B ($f_{s2}/2$), having the rate equal to $f_{s2}/2$, are converted into the digital color difference signals C_R (f_{s2}) and C_B (f_{s2}) having the rate equal to f_{s2}, for the playback mode.

The clock rate used in the D/A converting unit 61 is also changed over to $2f_{s2}$, f_{s2} and f_{s2}. Since the frequencies f_{s1} and f_{s2} are rather close to each other, the post-filters 61PRY, $61PFC_R$ and $61PFC_B$ may be used in common without changing their characteristics.

As for the word length, a word length of the order of 10 bits suffices for signals Y, C_R and C_B of the digital interface and the D/A converter 61 . However, the word length for the signals Y, C_R and C_B to be supplied to the second digital processing unit 5 needs to be set to a value one or two bits longer in view of the rounding errors brought about in the rate converting circuit.

In the present embodiment, 11-bit signals Y, C_R and C_B are generated by the first digital processing unit 4 and upper 10 bits of the signals Y, C_R and C_B are supplied to the D/A converter 61. The second digital processing unit 5 performs processing with a number of bits two to three bits larger and rounding to 10 bits is performed at an end stage.

Concrete examples of the rate converting circuit 50Y for luminance signals and the rate converting circuit 50C for color difference signals 50C, making up the above-mentioned second digital processing unit 5, are explained.

The rate converting circuit 50Y for luminance signals is made up of a half bandfilter 51Y, a rate conversion filter 52Y, a rounding circuit 53Y, a delay compensating circuit 54Y, a zero-stuffing circuit 55Y and first to sixth changeover circuits $56Y_1$ to $56Y_6$ for changing oven the input and the output, as shown in FIG. 4.

For the recording mode, the digital luminance signals Y ($2f_{s1}$) having the rate $2f_{s1}$, generated by the first digital

processing unit 4, are entered to the half-band filter 51Y so as to be sequentially passed through the rate conversion filter 52Y, rounding circuit 53Y and the delay compensating circuit 54Y, so as to be rate-converted into digital luminance signals $Y(f_{s2})$ having the data rate equal to f_{s2}, as shown in FIG. 3.

The half band filter 51Y has a passband of $f_{s2}/2$ for the digital luminance signals $Y(2f_{s1})$ pertaining to the rate $2f_{s1}$, at an output data rate of $2f_{s1}$. Thus the half band filter has characteristics of functioning as a Nyquist filter for the rate equal to f_{s2}. In the present embodiment, the characteristics are so set that 0±0.1 dB (~5.75 MHz), <−12 dB (~6.75 MHz), <−40 dB (8.0 MHz).

On the other hand, the rate converting filter 52Y suppresses 1st to (n-1)th order carrier components of the higher order carrier components contained in the digital luminance signals $Y(2f_{s1})$ having the rate $2f_{s1}$ supplied via the half band filter 51Y. The rate converting filter 52Y includes an equalizing filter operated at the rate equal to $2f_{s1}$ for compensating the attenuation produced in the above-mentioned band of the half band filter 51Y.

The digital luminance signals $Y(f_{s2})$, produced by the rate converting filter 52Y, are processed by the rounding circuit 53Y with scaling, clipping and Founding and subsequently processed with delay compensation with respect to the color difference signal channel by the delay compensation circuit 54 before being outputted.

It is noted that the rate converting circuit 50Y for luminance signals performs rate conversion of from 2 m to n for a frequencies $f_{s2}=f_{s1}\cdot n/m$, where m and n are positive integers. For coping with a system in which plural f_{s1} rates exist, depending on the number of pixels of the EIA/CCIR OF CCD image sensors, plural rate conversion rates may be variably set, as shown in Table 1, so that the operation may be made with plural modes.

TABLE 1

modes	relation between f_{s1} and f_{s2}	$f_{s1}(f_H)$	$f_{s2}(f_H)$	rate conversion ratio
mode 0	$f_{s2}=\frac{33}{35}f_{s1}$	14.31818 MHz ($910f_H$)	13.58 MHz ($858f_H$)	70→33
mode 1	$f_{s2}=\frac{18}{19}f_{s1}$	14.25 MHz ($912f_H$)	13.58 MHz ($858f_H$)	19→9
mode 2	$f_{s2}=\frac{12}{13}f_{s1}$	14.625 MHz ($936f_H$)	13.58 MHz ($858f_H$)	13→6
general formula	$f_{s2}=\frac{n}{m}f_{s1}$			2m→n

It is necessary for the rate conversion circuit 50Y to change the characteristics and operation of the rate conversion responsive to the respective modes. However, since the values of f_{s1} are closer for the respective modes, the half band filter 51Y may have common characteristics, while it is only necessary to change the characteristics and operation of the rate conversion filter 52Y.

Also, for the playback mode, the rate converting circuit 50Y for luminance signals has its first to sixth changeover circuits $56Y_1$ to $46Y_6$ set as shown in FIG. 6.

That is, for the playback mode, the f_{s2} rate digital luminance signals $Y(f_{s2})$ reproduced by the recording/replay unit 7 are supplied to the delay compensation circuit 54Y for delay compensation with respect to the color difference signal channel before being outputted via 0-stuffing circuit 55Y to the half band filter 51Y.

The 0 stuffing circuit 55Y inserts 0s between samples for up-conversion of the digital luminance signals $Y(f_{s2})$ having the rate equal to f_{s2} to the rate of $2f_{s2}$. For the replay mode, the half band filter plays the role of a rate-raising converting filter of raising the frequency from f_{s2} to $2f_{s2}$ by suppressing odd-number order carrier components for the digital luminance signals $Y(f_{s2})$ having the rate equal to $2f_{s2}$.

The digital luminance signals $Y(f_{s2})$ having the data rate equal to $2f_{s2}$ produced by the half band filter 51Y are processed by the rounding circuit 53Y with scaling, clipping and rounding before being outputted.

Meanwhile, the rate converting filter 52Y is not employed for replay.

The rate converting circuit 50C for color difference signals is made up of a multiplexor/demultiplexor (MPX/DMPX) 51C, a half band filter 52C, a rate converting filter 53C, a rounding circuit 54C, a 0-stuffing circuit 55C and first to fourth changeover circuits $56C_1$ to $56C_4$, as shown in FIG. 7.

For the recording mode, the rate conversion circuit 50C has its first to fourth changeover circuits $56C_1$ to $56C_4$ set as shown in FIG. 8.

That is, for the recording mode, the f_{s1} rate digital color difference signals $C_R(f_{s1})$, $C_B(f_{s1})$, generated by the first digital processing unit 4, are arrayed in a point-sequential manner by the multiplexor/demultiplexor (MPX/DFPX) 51C, so as to be entered as the $2f_{s1}$ rate digital point-sequential color difference signals $C_R/C_B(2f_{s1})$ to the half band filter 52C. The digital point-sequential color difference signals are passed through the rate converting filter 53C and the rounding circuit 54C, in this order, so as to be outputted as the f_{s2} rate digital point-sequential color difference signals $C_R/C_B(f_{s2})$.

The half band filter 52C has a passband of f_{s2} for the digital point-sequential color difference signals $C_R/C_B(2f_{s1})$, at an output data rate of $2f_{s1}$. Thus the half band filter has characteristics of functioning as a Nyquist filter for the rate equal to f_{s2}.

On the other hand, the rate converting filter 53C suppresses the 1st to (n-1)th order carrier components of the higher order carrier components contained in the digital luminance signals $C_R/C_B(2f_{s1})$ with the rate $2f_{s1}$, supplied via the half band filter 52C. The rate converting filter 53C includes an equalizing filter operated at the rate equal to $2f_{s1}$ for compensating the attenuation produced in the above-mentioned band of the half band filter 52C.

The digital point-sequential f_{s2} rate for the digital point-sequentially color difference signals $C_R/C_B(f_{s2})$, produced by the rate converting filter 53C, are processed by the rounding circuit 54C with scaling, clipping and rounding before being outputted.

It is noted that the rate converting circuit 50C performs rate conversion of from 2 m to n for frequencies $f_{s2}=f_{s1}\cdot n/m$, where m and n are positive integers. For coping with a system in which plural f_{s1} rates exist, depending on the number of pixels of the EIA/CCIR or CCD image sensors, plural rate conversion rates may be variably set so that the operation may be made with plural modes.

It is necessary for the rate conversion circuit 50C to change the characteristics and operation of the rate conversion responsive to the respective modes. However, since the values of f_{s1} are closer for the respective modes, the half band filter 52C may have common characteristics, while it is only necessary to change the characteristics and operation of the rate conversion filter 53C.

Also, for the playback mode, the rate converting circuit **50C** for luminance signals has its first to fourth changeover circuits **56C**$_1$ to **56C**$_4$ set as shown in FIG. 9.

That is, for the playback mode, the f_{s2} rate digital point-sequential color difference signals C_R/C_B (f_{s2}) reproduced by the recording/replay unit **7** are supplied via 0-stuffing circuit **55C** to the half band filter **52C**.

The 0 stuffing circuit **55C** inserts 0s between samples for up-conversion of the digital point-sequential color difference signals C_R/C_B (f_{s2}) to the rate of $2f_{s2}$. For the replay mode, the half band filter **52C** plays the role of a rate-raising converting filter of raising the frequency from f_{s2} to $2f_{s2}$ by suppressing odd-number order carrier components for the $2f_{s2}$ rate digital point-sequential color difference signals C_R/C_B (f_{s2}).

The $2f_{s2}$ rate digital point-sequential color difference signals C_R/C_B ($2f_{s2}$), produced by the half band filter **52C**, are processed by the rounding circuit **54C** with scaling, clipping and rounding and arrayed into concurrent signals by the MPX/DMPX **51C** before being outputted as f_{s1} rate digital color difference signals C_R (f_{s1}) and C_B (f_{s1}).

Meanwhile, the rate converting filter **53C** is not employed for the playback mode.

In this manner, the rate converting circuit **50C** for color difference signals handles the f_{s1} rate digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) as the $2f_{s1}$ rate digital point-sequential color difference signals C_R/C_B, so that the hardware may be diminished in scale, while it becomes possible to use the processing of the same nature for the two color difference signals.

Meanwhile, in the present embodiment, in an output stage of the luminance signal channel of the second digital processing circuit **42** in the above-mentioned digital processing unit **4**, a delay compensation circuit **42DLY** is provided in a luminance signal channel.

The delay compensation circuit **42DLY** is used for compensating the delay caused in the low-pass filters **63C**$_R$, **63C**$_B$ of the analog encoder **62** in the signal processing unit for analog output **6**. The delay quantity of the delay compensation circuit **42DLY** is so set that, if only the component signals Y, C_R and C_B from the signal processing unit **6** are used, the delay compensation circuit is used for compensating the delay caused in the post-filters **61PFY**, **61PFC**$_R$ and **61PFC**$_B$ of the D/A converting unit **61** and, if the component signals Y, C_R and C_B are not used but the composite signal CS or Y/C is used, the delay compensation circuit is used for compensating the delay of the low-pass filters **63C**$_R$, **63C**$_B$ of the analog encoder **62**.

Meanwhile, the difference in delay between the post filter **61PRY** and the post filters **61PFC**$_R$ and **61PFC**$_B$ is usually of a small value on the order of one or two clocks based on the f_{s1} rate and may be corrected at any location in the processing system.

Besides, in the present embodiment, the respective delay quantities are so set that, with the delay quantity of each of the low-pass filters **63C**$_R$ and **63C**$_B$ of the analog encoder **62** equal to DL_{LPF}, the delay quantity of a delay compensation circuit **66** thereof being DL_0, the delay quantity of the delay compensation circuit **42DLY** provided at the output stage of the luminance signal channel of the first digital processing unit **4** being DL_1, the delay quantities of the half band filter **52Y**, rate converting filter **53Y** and the delay compensation circuit **54Y** of the rate converting circuit **50Y** for the luminance signals being DL_2, DL_3 and DL, respectively, and with the delay quantities of the half band filter **52C** and the rate converting filter **53C** of the rate converting circuit **50C** for the color difference signals being DL_4 and DL_5, respectively, the equations

$$DL_1+DL_2+DL_3+DL=DL_4+DL_5$$

and

$$DL_2+DL_0=DL_4+DL_{LPF}$$

hold for the recording and playback modes, respectively.

It is noted that the effective processing rate of the rate converting circuit **50C** for color difference signals is lower than that of the rate converting circuit **50Y** for luminance signals, such that the inequalities $DL_2<DL_4$ and $DL_3<DL_5$ hold.

An illustrative operation of the rate converting circuit **50Y** for the luminance signals for converting the $2f_{s1}$ rate digital luminance signal Y ($2f_{s1}$) generated by the first digital processing unit **4** into f_{s2} rate digital luminance signal Y (f_{s2}) is explained for the rate conversion ratio of from 19 to 9, that is for $f_{s2}=18f_{s1}/19$, by referring to the spectrum diagram shown in FIG. **10** and to the timing chart shown in FIG. **11**.

That is, for the recording mode, the $2f_{s1}$ rate digital luminance signal Y ($2f_{s1}$) with the spectrum as shown at (A) in FIG. **10**, generated by the first digital processing unit **4** (bandwidth: 0–f_{s1}), is bandwidth-limited to the Nyquist frequency with respect to the f_{s2} rate, by half-band filter **51Y** having characteristics shown at (B) in FIG. **10**, so as to be supplied to the rate converting filter **52Y** as $2f_{s1}$ rate digital luminance signal Y ($2f_{s1}$) (bandwidth: 0–$f_{s2}/2$).

That is, the digital luminance signal Y ($2f_{s1}$), constituted by a set of samples $\{a_n\}$ with the rate equal to $2f_{s1}$, shown at (A) in FIG. **11**, is bandwidth-limited by the half band filter **51Y** to the Nyquist frequency with respect to the $f_{s2}/2$ rate, so as to be supplied to the rate converting filter **52Y**.

For the set of samples $\{b_n\}$, having the $2f_{s1}$ input rate, the rate converting filter **52Y** divides the interval between neighboring samples into nine equal parts, and causes the original samples to remain at points where the samples $\{b_m\}$ exist, shown by 0 at (B) in FIG. **11**, while stuffing 0 samples at points where the samples $\{b_m\}$ are absent, as indicated by dots at B in FIG. **11**, for transforming the sample set into a set of samples $\{b_p\}$ having a rate of $9\times2f_{s1}=18f_{s1}$. The rate converting filter **52Y** also generates a 18 f_{s1} rate interpolated samples by taking a convolution of the impulse response $\{h_p\}$ of the rate converting filter represented by the 18 f_{s1} rate and the sample set having the $18f_{s1}$ rate. Meanwhile, an imaginary interpolated sample set by the rate converting filter **52Y** and an output sample set having the f_{s2} rate $\{c_n\}$ are indicated by x and ⊙, at (B) in FIG. **11**, respectively.

The rate converting filter **52Y** has characteristics in which, as defined at (D) in FIG. **10**, it has a passband of $k\times18f_{s1}\leq f_c$, k being an integer, and a stop band of $g\times18f_{s1}\pm f_c$, g being an integer. Thus the rate converting filter **52Y** inhibits the $2f_{s1}$ sampling carrier components in the vicinity of $2f_{s1}$ and 4 to 16 f_{s1} of the $2f_{s1}$ rate digital luminance signals Y($2f_{s1}$) supplied from the half band filter **51Y**, indicated at (C) in FIG. **10**. In this manner, the $2f_{s1}$ rate digital luminance signal Y ($2f_{s1}$) are turned into digital luminance signal Y ($18f_{s1}$), raised to a rate nine times as much as the original rate, or $18f_{s1}$ rate.

The bandwidth characteristics of the digital luminance signals Y ($18f_{s1}$) represent the f_{s2} rate Nyquist characteristics as defined by the half band filter **51Y**.

It should be noted that the filtering to the $18f_{s1}$ rate is imaginary and in effect an output sample set $\{c_n\}$ having the rate equal to f_{s2} produced by down-sampling the $18f_{s1}$ rate output sample train for every 19 samples.

Therefore, the convolution between the $18f_{s1}$ rate impulse response $\{h_p\}$ and the $18f_{s1}$ rate sample set $\{b_p\}$ needs to be carried out for the case of the sample train $\{b_p\}$ being non-zero sample train $\{b_m\}$, such that it suffices to carry out the processing operations of

$$
\begin{aligned}
c_0 &= h_{-9}\, b_1 + h_0\, b_0 + h_9\, b_{-1} \\
c_1 &= h_{-8}\, b_3 + h_1\, b_2 + h_{10}\, b_1 \\
c_2 &= h_{-7}\, b_5 + h_2\, b_4 + h_{11}\, b_3 \\
c_3 &= h_{-6}\, b_7 + h_3\, b_6 + h_{12}\, b_5 \\
c_4 &= h_{-5}\, b_9 + h_4\, b_8 \\
c_5 &= h_{-4}\, b_{11} + h_5\, b_{10} \\
c_6 &= h_{-12}\, b_{14} + h_{-3}\, b_{13} + h_6\, b_{12} \\
c_7 &= h_{-11}\, b_{16} + h_{-2}\, b_{15} + h_7\, b_{14} \\
c_8 &= h_{-10}\, b_{18} + h_{-1}\, b_{17} + h_8\, b_{16}
\end{aligned}
$$

These processing operations may be carried out at e.g. the f_{s1} rate or at the f_{s2} rate.

In the above-mentioned rate converting operations by the rate converting circuit **50Y**, the following three conditions are characteristically critical.

First condition: That the $2f_{s1}$ rate digital luminance signal Y ($2f_{s1}$), supplied to the half band filter **51Y**, shown at (A) in FIG. **10**, has the same characteristics as those of the $18f_{s1}$ rate digital luminance signals Y($18f_{s1}$), shown at (E) in FIG. **10**, rate-raised by the rate converting filler **52Y** to the $18f_{s1}$ rate which is imaginarily nine times as much as the original rate, as long as the bandwidth of from 0 to f_c is concerned, that is that the bandwidth of 0 to f_c of the characteristics of the product of the characteristics of the half band filter **51Y** shown at (B) in FIG. **10** and those of the rate converting filter **52Y** shown at (D) in FIG. **10** may be approximated to unity.

Second Condition: That $2f_{s1}$ sampling carrier components of the digital luminance signals Y($18f_{s1}$), rate-raised to $18f_{s1}$ rate, shown at (E) in FIG. **10**, be suppressed sufficiently, as long as the range of from f_c to ($18f_{s1}-f_c$) is concerned, that is that the characteristics of the product of the characteristics of the half band filter **51Y** shown at (B) in FIG. **10** and the characteristics of the rate converting filter **52Y** shown at (B) in FIG. **10** may be approximated to 0 as long as the range of from f_c to ($18f_{s1}-f_c$) is concerned, above all that the characteristics of the rate converting filter **52Y** shown at (D) in FIG. **10** becomes 0 as long as the range of from $2f_{s1}$ to $16f_{s1}$ is concerned and no ($\alpha 2f_{s1}-\beta f_{s2}$) component is generated at the output when the input is the direct current, and further that the characteristics of the product of the characteristics of the half band filter **51Y** shown at (B) in FIG. **10** and those of the rate converting filter **52Y** shown at (D) in FIG. **10** be sufficiently suppressed as long as the range of from $1f_{s2}$ to $18f_{s2}$ is concerned.

Third Condition: That the filter characteristics of the rate converting circuit **50Y** be so set that the frequency characteristics in the vicinity of f_c of the digital luminance signal Y ($18f_{s1}$) shown at (E) in FIG. **10**, raised in rate to imaginarily to nine times as much as the original frequency, or to $18f_{s1}$ rate, by the rate converting filter **52Y**, be within a prescribed value range.

With the rate converting circuit **51** of the present embodiment, the $2f_{s1}$ rate digital luminance signal Y ($2f_{s1}$) is first passed through the half band filter **51Y** to satisfy the first and the second conditions, while the third condition may be satisfied by the rate converting filter **52Y**. Besides, since the half band filter **51Y** is an FIR filter having a fixed coefficient, the circuit size may be reduced by employing various filter designing methods. The rate converting filter **52Y**, which is a variable coefficient filter, necessitates a multiplier. However, it may be constructed easily because it has smooth roll-off characteristics and subjected to only little constraint concerning the stop band, as shown at (D) in FIG. **10**.

For example, the impulse response $\{h_p\}$ of the rate converting filter **52Y** may be expressed by 24 orders of

$$\{1, 3, 6, 10, 15, 21, 28, 35, 43, 49, 54, 57, 58, 57 \ldots\}/78$$

while three of the multipliers of the rate converting filter **52Y** suffice. The word length of the coefficient becomes 6 bits in his case to simplify the coefficient generator or the multiplier.

The rate converting filter **52Y** of the rate converting circuit **51** may be constructed as shown for example in FIG. **12**.

The rate converting filter **52Y** shown in FIG. **12** executes the above-mentioned processing operations at the output rate of f_{s2} to generate a sample train or set $\{c_n\}$ of the f_{s2} rate from the sample train $\{b_n\}$ of the $2f_{s1}$ rate. Thus it is made up of four-stage shift registers **151**, a data re-arraying circuit **152**, latch circuits **153A**, **153B** and **153C**, three coefficient generators **154A**, **154B** and **154C**, multipliers **155A**, **155B** and **155C**, an adder **156** and a latch circuit **157**.

The sample train $\{b_n\}$ of the $2f_{s1}$ rate, shown at (A) in FIG. **13**, is supplied in series to the shift register **151** of the rate converting filter **52Y**. The shift register **151** is operated by the $2f_{s1}$ rate clocks CK ($2f_{s1}$) for sequentially delaying the sample train $\{b_n\}$ of the $2f_{s1}$ rate. A 1-clock delay output, a 2-clock delay output, a 3-clock delay output, and a 4-clock delay output, shown at (B), (C), (D) and (E) in FIG. **13**, of the sample train $\{b_n\}$, produced by the four-stage shift register **151**, are supplied in parallel to the data re-arraying circuit **152**, at the $2f_{s1}$ rate.

The data re-arraying circuit **152** re-arrays at the f_{s2} rate the 1-clock delay output, 2-clock delay output, 3-clock delay output and the 4-clock delay output, entered in parallel from the shift register **151** at the $2f_{s1}$ rate, for generating three different sample trains $\{b_n\}_A$, $\{b_n\}_B$ and $\{b_n\}_C$ employed for the above processing operations, as shown at (F), (G) and (H) in FIG. **13**. The f_{s2} rate sample trains $\{b_n\}_A$, $\{b_n\}_B$ and $\{b_n\}_C$, generated by the data re-arraying circuit **152**, are supplied via the latch circuits **153A**, **153B** and **153C** to the multipliers **154A**, **154B** and **154C**.

On the other hand, the coefficient generators **155A**, **155B** and **155C** sequentially generate the three different multiplication coefficients A_{COEF}, B_{COEF} and C_{COEF}, employed for the above-mentioned processing operations. Of these coefficient generators **155A**, **155B** and **155C**, the coefficient generator **155A** sequentially supplies the multiplication coefficients A_{COEF} $\{h_{-9}, h_{-8}, h_{-7}, h_{-6}, h_{-5}, 0, h_{-12}, h_{-11}$ and $h_{-10}\}$, as shown at (I) in FIG. **13**, to the multiplier **154A**. The coefficient generator **155B** sequentially supplies the multiplication coefficients B_{COEF} $\{h_0, h_1, h_2, h_3, h_4, h_{-4}, h_{-3}\ h_{-2}$ and $h_{-1}\}$, as shown at (J) in FIG. **13**, to the multiplier **154B**, while the coefficient generator **155C** sequentially supplies the multiplication coefficients C_{COEF} $\{h_9, h_{10}, h_2, h_{11}, h_{12}, 0, h_5, h_6, h_7$ and $h_8\}$, as shown at (K) in FIG. **13**, to the multiplier **154C**.

The multipliers **154A**, **154B** and **154C** perform an operation of parallel multiplication of multiplying the latch outputs of the latch circuits **153A**, **153B** and **153C**, that is the f_{s2} rate sample trains $\{b_n\}_A$, $\{b_n\}_B$ and $\{b_n\}_C$, generated by the data re-arraying circuit **152**, by the different multiplication coefficients A_{COEF}, B_{COEF} and C_{COEF} supplied from the coefficient generators **155A**, **155B** and **155C**, at the f_{s2} rate. The multiplication outputs of the multipliers **154A**, **154B** and **154C** are supplied to the adder **156**.

The adder **156** adds the multiplication outputs of the multipliers **154A**, **154B** and **154C** to calculate the f_{s2} rate sample trains $\{c_n\}$, that is

$$c_0 = h_{-9}b_1 + h_0 b_0 + h_9 b_{-1}$$

$$c_1=h_{-8}b_3+h_1b_2+h_{10}b_1$$

$$c_2=h_{-7}b_5+h_2b_4+h_{11}b_3$$

$$c_3=h_{-6}b_7+h_3b_6+h_{12}b_5$$

$$c_4=h_{-5}b_9+h_4b_8$$

$$c_5=h_{-4}b_{11}+h_5b_{10}$$

$$c_6=h_{-12}b_{14}+h_{-3}b_{13}+h_6b_{12}$$

$$c_7=h_{-11}b_{16}+h_{-2}b_{15}+h_7b_{14}$$

$$c_8=h_{-10}b_{18}+h_{-1}b_{17}+h_8b_{16}$$

The f_{s2} rate sample trains $\{c_n\}$, generated from the $2f_{s1}$ rate sample trains $\{b_n\}$, are sequentially outputted via latch circuit 157, as shown at (M) in FIG. 13.

For the present concrete example of $f_{s2}=18f_{s1}/19$, it suffices to cause the multiplication coefficients A_{COEF}, B_{COEF} and C_{COEF}, employed for the above-mentioned processing operations, to appear cyclically at the interval of nine clocks of f_{s2}, so that the coefficient generators **155A**, **155B** and **155C** may be easily arranged as shift registers, as shown for example in FIG. 14.

The coefficient generator **155**, shown in FIG. 14, is made up of first to third shift registers **161**, **162** and **163**, connected in tandem, a first switching circuit **164** for changing over the clocks of the shift registers **161**, **162** and **163**, a second switching circuit **165** for changing over the outputs and a control circuit **166** for controlling the operation of the switching circuits **164**, **165**.

Each of the first to third shift registers **161** to **163** has its clock input terminal selectively connected via the first switching circuit **164** to first or second clock input terminals **160A** or **160B**. Besides, the first shift register **161** has its data input terminal selectively connected via the second switching circuit **165** to a data output terminal of the first shift register **161**, a data output terminal of the second shift register **162**, a data output terminal of the third shift register **163** or a coefficient data input terminal **160C**. The first shift register **161** is a six-stage shift register having its data output terminal connected to the coefficient data output terminal **155C**. The second shift register **162** and the third shift register **163** are three-stage and 24-stage shift registers, respectively.

The first clock input terminal **160A** is supplied with f_{s2} rate clocks CK (f_{s2}). The second clock input terminal **160B** is supplied with load clocks LDCKI from a system controller, not shown. The coefficient data input terminal **160C** is supplied with coefficient data COEFI from the system controller, while the control circuit **166** is supplied from the synchronizing signal generator **11** with a horizontal synchronizing signal HD from the synchronizing signal generator **11**, while being supplied with a mode signal MODEI from the system controller.

In the present coefficient generator **155**, the switching circuits **164** and **165** are controlled in the following manner by the control circuit **166** responsive to the mode signal MODEI supplied from the system controller, not shown.

That is, when starting the camera operation, the first switching circuit **164** selects the load clock LDCKI supplied from the system controller. During the normal operation, the first switching circuit **164** selects the f_{s2} rate clock CK(f_{s2}).

When starting the camera operation, the second switching circuit **165** selects the coefficient data COEFI supplied from the system controller. During the normal operation, the second switching circuit **165** selects output data of the first to third shift registers **161** to **163**, that is, it selects the output data of the first shift register **161**, the output data of the second shift register **162** or the output data of the third shift register **163** for the modes **1**, **2** and **3**, respectively,

With the above-described arrangement of the coefficient generator **155**, the coefficient data COEFI required for rate conversion at the desired rate conversion ratio is supplied, at the time of starting the camera, from the system controller to the data input terminal of the shift register SR1 via the second switching circuit **165** for synchronized writing at the required stage numbers of the first to third shift registers **161** to **163** by the load clocks LDCK for setting the coefficient data COEFI having the desired conversion ratio in the first to third shift registers **161** to **163**.

For the normal operation, the coefficient data as set in the first to third shift registers **161** to **163** are recycled responsive to the operating mode by clocks CK (f_{s2}) at the f_{s2} rate for real-time outputting of the multiplication coefficient COEFI required for rate conversion at the desired rate conversion ratio.

That is, for mode **1**, by recycling the coefficient data COEFI as set in the first shift register **161** at the f_{s2} rate by the clocks CK (f_{s2}), wherein, according to the equation $f_{s2}=12f_{s1}/13$, the multiplication coefficient COEF necessary for rate conversion at the rate conversion ratio of from 13 to 6 is outputted.

For mode **2**, by recycling the coefficient data COEFI as set in the first shift register **161** and the second shift register **162** at the f_{s2} rate by the clocks CK (f_{s2}), wherein, according to the equation $f_{s2}=18\ f_{s1}/19$, the multiplication coefficient COEF necessary for rate conversion at the rate conversion ratio of from 19 to 9 is outputted.

For mode **3**, by recycling the coefficient data COEFI as set in the first shift register **161**, second shift register **162** and in the third shift register **163** at the f_{s2} rate by the clocks CK (f_{s2}), wherein, according to the equation $f_{s2}=33f_{s1}/35$, the multiplication coefficient COEF necessary for rate conversion at the rate conversion ratio of from 70 to 33 is outputted.

The coefficient generator **155** may be constructed by a random access memory **171**, an address control circuit **172**, a control circuit **173** etc., as shown in FIG. 15.

In the coefficient generator **155**, shown in FIG. 15, the control circuit **173** performs the following control operations responsive to the mode signal MODEI supplied from the system controller, not shown.

That is, when starting the camera, the address control circuit **172** is controlled for generating write addresses responsive to load clocks LDCK supplied from the system controller, not shown, while controlling the random access memory **171**. During the normal operation, the control circuit **173** controls the address control circuit **172** for generating the readout addresses responsive to the f_{s2} rate clocks CK (f_{s2}), while controlling the readout of the random access memory **171**.

When starting the camera, the coefficient data COEFI, necessary for rate conversion at the desired rate conversion ratio is written from the system controller, not shown, in the random access memory **171** via the control circuit **173**. During the normal operation, the coefficient data COEFI as set in the random access memory **171** is repeatedly read at the f_{s2} rate by the clocks CK (f_{s2}), while the multiplication coefficient COEF required for rate conversion at the desired rate conversion ratio is outputted on the real-time basis via the latch circuit **174**.

On the other hand, the rate conversion circuit **50C** for color difference signals in the present embodiment handles digital color difference signals $C_R(f_{s1})$ and C_B (f_{s1}), having the rate equal to f_{s1}, as $2f_{s1}$ rate digital point-sequential color

difference signals C_R/C_B, as mentioned above. Similarly to the rate conversion circuit 50Y for luminance signals, the rate converting circuit 50C for the above-mentioned luminance signals performs the rate conversion of from 2 m to n with the frequencies given by $f_{s2}=f_{s1}\cdot n/m$, with m and n being positive integers, as shown in timing charts of FIGS. 16 and 17, showing the operation for the rate conversion ratio of $f_{s2}=18f_{s1}/19$, that is from 19 to 9.

The rate conversion filter 53C for the rate conversion circuit 50C for color difference signals may be constructed similarly to the rate conversion filter 52Y for the rate conversion circuit 50Y for luminance signals. Thus, as shown in FIG. 18, the rate conversion filter 53C is made up of a four-stage shift register 251, a data re-arraying circuit 252, latch circuits 253A, 253B and 253C, three multipliers 254A, 254B and 254C, coefficient generators 255A, 255B and 255C, an adder 256 and a latch circuit 257, as shown in FIG. 18.

The coefficient generators 255A, 255B and 255C of the rate conversion filter 53C may be made up of first to third shift registers 261, 262 and 263, connected in tandem, a first switching circuit 264 for changing over the clocks of the shift registers 261, 262 and 263, a second switching circuit 265 for changing over the outputs and a control circuit 266 for controlling the operation of the switching circuits 264, 265, as shown in FIG. 19, or of a random access memory 271, an address control circuit 272 and a control circuit 273 etc., as shown in FIG. 20.

Since the operation of the rate conversion filter is the same as that of the rate converting filter 52Y for luminance signals, the corresponding operation is not made for brevity.

It will be noted that, in the rate converting operation indicated by $n\times 2f_{s1}=mf_{s2}$, such as rate conversion of from 19 to 9 for m=19 and n=9, the $2f_{s1}$ rate input data set has a large energy at a frequency an integer number 1–(n–1) of times of $2f_{s1}$. Thus it suffices for the rate converting filter performing the rate conversion to have filter characteristics which will suppress the carrier components of these frequencies and higher-order carrier side band frequencies. Thus the rate conversion filter needs to have an impulse response of an integer number coefficient given by developing a product $H_1(z^{-1})\times H_2(z^{-1})$ of a first transfer function $H_1(z^{-1})$ having a zero point at the frequency $n\times 2f_{s1}$ and a second transfer function $H_2(z^{-1})$ having zero points above and below the frequency $n\times 2f_{s1}$.

That is, it is possible for the rate converting filter 52Y for luminance signals to have an impulse response of an integer coefficient having at least one zero point at $n\times 2f_{s1}$ and two zero points in the vicinity thereof, while it is possible for the rate converting filter 53C for color difference signals to have an impulse response of an integer coefficient having at least one zero point at $n\times f_{s1}$ and two zero points in the vicinity thereof.

The first and second transfer functions $H_1(z^{-1})$ and $H_2(z^{-1})$ may for example be given by the following equations:

$$H_1(z^{-1})=\sum_{p=0}^{n-1} Z^{-p} \qquad \text{(equation 1)}$$

$$H_2(z^{-1})=\left\{\sum_{p=0}^{n-1} Z^{-p}\right\}^2-H_0(z^{-1}) \qquad \text{(equation 2)}$$

The first transfer function $H_1(z^{-1})$ has an (n–1)th order integer coefficient and is given for example by

$$H_1(z^{1})=1+z^{-1}+z^{-2}+z^{-3}+z^{-4}+z^{-5}+z^{-6}+z^{-7}+z^{-8}.$$

The second transfer function $H_2(z^{-1})$ has an 2(n–1)th order integer coefficient and is given for example by

$$\begin{aligned}H_1(z^{-1}) &= 1+2z^{-1}+3z^{-2}+4z^{-3}+5z^{-4}+6z^{-5}+\\ &\quad 7z^{-6}+8z^{-7}+9z^{-8}+z^{-16}+2z^{-15}+\\ &\quad 3z^{-14}+4z^{-13}+5z^{-12}+6z^{-11}+7z^{-10}+\\ &\quad 8z^{-9})-(z^{-7}+2z^{-8}+z^{-9})\\ &= 1+2z^{-1}+3z^{-2}+4z^{-3}+5z^{-4}+6z^{-5}+\\ &\quad 7z^{-6}+7z^{-7}+7z^{-8}+7z^{-9}+7z^{-10}+\\ &\quad 6z^{-11}+5z^{-12}+4z^{-13}+3z^{-14}+\\ &\quad 2z^{-15}-(z^{-16})\end{aligned}$$

whereby the rate conversion filter has a 3nth order integer coefficient and has characteristics as shown in FIG. 21. Meanwhile, z^{-1} is a unit delay operator corresponding to $n\times 2f_{s1}$.

With the data string entered to the rate converting filter, since real samples are present at an interval of n with respect to the impulse response of the rate converting filter, three multipliers suffice for performing an actual convolution. By operating the rate converting filter only for suppressing high carrier components of $2f_{s1}$, the number of the multipliers necessary for the actual circuit may be diminished. Although the roll-off of the amplitude characteristics becomes blunt in the vicinity of the base band, it may be corrected in advance by the half band filter.

With the above-described digital cam corder, the image pickup signals R, G and B outputted from the solid-state image sensors 1R, 1G and 1B of the image pickup unit 1 driven at the f_{s1} rate are digitized at the f_{s1} rate at the predetermined phase by the A/D converting unit 3, and at least the digital luminance signals Y and the two digital color difference signals C_R and C_B are generated by the first digital processing unit 4 operated at a clock rate related with the f_{s1} rate, so that digital picture signals having an excellent picture quality may be obtained without suffering from beat interference.

For the recording mode, as shown in FIG. 22 showing the operating state during recording, the f_{s1} rate related digital luminance signals Y and the two digital color difference signals C_R and C_B, generated by the first digital processing unit 4, are converted by the second digital processing unit 5 into f_{s2} rate related digital luminance signals Y and two digital color difference signals C_R, C_B so as to be supplied to the recording/reproducing unit 7, while the f_{s1} rate related digital luminance signals Y and the two digital color difference signals C_R, C_B are outputted via the signal processing unit 6 for analog output 6. Also, as shown in FIG. 23 showing the operating state during the playback mode, the f_{s2} rate related digital luminance signals Y and the two digital color difference signals C_R, C_B, reproduced by the recording/reproducing unit 7 are converted by the second digital processing unit 5 into f_{s1} rate related digital luminance signals Y and the two digital color difference signals C_R and C_B so as to be outputted via the signal processing unit for analog output 6.

That is, with the present digital cam corder, the second digital processing unit 5 has the function of bidirectional rate conversion between the f_{s1} rate related data rate and the f_{s2} rate related data rate. Thus, for the recording mode, the second digital processing unit 5 outputs the digital luminance signals Y and the two digital color difference signals C_R and C_B, generated by the first digital processing unit 4, via the signal processing unit 6, while supplying the same signals to the recording/reproducing unit 7 via the second

digital processing unit 5. For the playback mode, the second digital processing unit 5 supplies the f_{s2} rate related data rate signals Y, C_R and C_B, reproduced by the recording/reproducing unit 7, to the signal processing unit 6 via the second digital processing unit 5, while outputting playback signals via the signal processing unit 6, so that the f_{s2} rate related data rate signals Y, C_R and C_B may be recorded and/or reproduced by the recording/reproducing unit 7.

Besides, with the present digital cam corder, the second digital processing unit 5 may set plural rate conversion ratio, the input data signals Y, C_R and C_B related to the f_{s1} rate are converted to the output data signals Y, C_R, and C_B related to the f_{s2} rate. So that, by employing the standard CCD image sensor as CCD image sensor 1R, 1G and 1B of the image pick-up unit 1, the digital imaging signal at D-1 standard clock rate or other clock rate may be obtained.

On the other hand, with the present digital cam corder, the first digital processing unit 4 generates the $2f_{s1}$ rate digital luminance signals Y ($2f_{s1}$), while the second digital processing unit 5 performs rate conversion of from $2f_{s1}$ to f_{s2} on the digital luminance signals Y ($2f_{s1}$), for the recording mode. Besides, for the playback mode, the second digital processing unit performs the rate conversion of from f_{s2} to $2f_{s1}$ or to $2f_{s2}$ on the f_{s2} rate digital luminance signals supplied from the recording/reproducing unit 7, so that it becomes possible to simplify the construction of the second digital processing unit.

On the other hand, the second digital processing unit 5 operates for the recording mode at the clock rates of $2f_{s2}$, f_{s2} and f_{s2} to play the role of a Nyquist filter for the signals Y($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}), with the clock rates of $f_{s2}/2$, $f_{s2}/4$ and $f_{s2}/4$. For the playback mode, the second digital processing unit 5 operates at the clock rates of $2f_{s1}$, f_{s1} and f_{s1}, so that the half bandfilters 51Y, 52C having the same frequency characteristics as those during the recording mode is employed for both the playback and recording modes. Thus, during the recording mode, the second digital processing unit 5 processes the signals Y($2f_{s1}$), C_R (f_{s1}) and C_B (f_{s1}), supplied from the rate converting filters 52Y and 53C via the half band filters 51Y and 52C, by performing the rate conversion of from $2f_{s1}$ to f_{s2} on the digital luminance signals Y ($2f_{s1}$), and by performing the rate conversion of from f_{s1} to $f_{s2}/2$ on the digital color difference signals C_R (f_{s1}) and C_B (f_{s1}). The construction of the second digital processing unit 5 may be simplified in this manner by employing the half band filters 51Y and 52C in common for the playback and recording modes.

Besides, the second digital processing unit 5 limits the bandwidth of the input data rate signals Y, C_R and C_B, generated by the first digital processing unit 5, by half band filters 51Y and 52C, having $f_{s2}/2$, $f_{s2}/4$ and $f_{s2}/4$ as the passbands, with the output data rate of $2f_{s1}$, f_{s1} and f_{s1}, and performs rate conversion of from $2f_{s1}$ to f_{s2}, f_{s1} to $f_{s2}/2$ or $f_{s2}/4$ and from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$ to output the low-order linear phase finite impulse response sufficient to suppress high order sideband components in the vicinity of $n\times 2f_{s1}$, $n\times f_{s1}$ and $n\times f_{s1}$, n being a positive integer, in the down-sampled form of f_{s2}, $f_{s2}/2$ or $f_{s2}/4$ and $f_{s2}/2$ or $f_{s2}/4$. The pass roll-off characteristics of the rate converting filters 52Y, 53C may also be compensated by the characteristics of the half band filters 51Y and 52C. This enables the rate conversion to be executed reliably by the second digital processing unit 5 of a simplified construction.

Besides, with the present digital cam corder, the rate converting filters 52Y and 53C for effecting rate conversion of the signals bandwidth-limited by the half band filters 51Y and 52C have an impulse response of an integer coefficient having at least one zero point at $n\times 2f_{s1}$, $n\times f_{s1}$ and $n\times f_{s1}$, and two zero points in the vicinity thereof, so that these filters may each be constructed by three multipliers 154A to 154C and 254A to 254C.

Besides, the half band filters 51Y, 52C for bandwidth limiting the input data rate signals Y, C_R and C_B, generated by the first, digital processing unit 4, may be of a simplified structure comprising products of partial filters constituted by integer coefficients.

With the present digital cam corder, the output image pick-up signals R, G and B of the solid-state image sensors 1R, 1G and 1B, arranged in the color-separating optical system of the image pickup unit 1 constructed in accordance with the spatial pixel shifting method, are digitized by the A/D converting unit 3 at the predetermined phase at the f_{s1} rate. At least the f_{s1} rate digital luminance signals Y ($2f_{s1}$) and two f_{s1} rate C_R (f_{s1}) and C_B (f_{s1}) are generated by the first digital processing unit 4, and rate conversion of from 2 m to n, where m and n are positive integers, is performed by the second digital processing unit 5 capable of setting plural rate conversion ratios n/m for generating digital luminance signals Y (f_{s2}) having the rate of $f_{s2}=f_{s1}\times n/m$ and digital color difference signals C_R ($f_{s2}/2$) and C_B ($f_{s2}/2$) having substantially the $f_{s2}/2$ rate, In this manner, high quality high MTF digital picture signals free of beat interference and aliasing distortion components may be produced in accordance with the spatial pixel shifting method.

With the present digital cam corder, the signals Y ($2f_{s1}$) and C_R (f_{s1}) and C_B (f_{s1}), generated by the first digital processing unit 4, are converted into analog signals by the D/A converting unit 61 of the signal processing unit 6 to output analog luminance signals Y_{OUT} and analog color difference signals C_{ROUT} and C_{BOUT}, so that high resolution analog picture signals and high MTF digital picture signals with little aliasing distortion components may be produced simultaneously. The signal processing unit 6 converts the $2f_{s1}$ rate digital luminance signals Y ($2f_{s1}$), generated by the first digital processing unit 4, into output analog signals by the D/A converting unit 61 for the recording mode, while converting the $2f_{s2}$ rate digital luminance signals Y ($2f_{s2}$), generated by the second digital processing unit 5, into output analog signals by the D/A converting unit 61 for the playback mode, so that high resolution analog luminance signals may be obtained for both the recording and playback modes.

With the above-described second digital processing unit 5, the digital luminance signal Y is interfaced by the digital interface 13 at the clock rate of $2f_{s2}$ and the digital color difference signals C_R and C_B are interfaced by the digital interface 13 at the clock rate of $f_{s2}/2$, so that the $2f_{s2}$ rate digital luminance signals Y ($2f_{s2}$) and the $f_{s2}/2$ clock rate digital color difference signals C_R ($f_{s2}/2$) and C_B ($f_{s2}/2$) may be exchanged with external equipment.

With the present digital cam corder, the first delay compensation circuit 42DLY for compensating the group delay caused by low-pass filters 63, 64 adapted for bandwidth-limiting the analog color difference signals in the analog encoder 62 supplied with analog luminance signals and analog color difference signals converted by the D/A converter 61 of the signal processing unit 6 from the signals Y, C_R and C_B generated by the first digital processing unit 4 is provided at the output stage of the luminance signal channel of the second digital processing circuit 42 of the first digital processing unit 4, so that the differential delay between the luminance signal Y and the color difference signals C_R and C_B generated by the CCD image sensors 1R, 1G and 1B of the image pickup unit 1 may be compensated to assure high quality analog picture signals.

With the present digital cam corder, since the second delay compensating circuit 54Y for outputting the f_{s2} rate related output data rate signals Y, C_R and C_B generated by the second digital processing unit 5 with an equalized group delay is provided in the rate converting circuit 50Y for luminance signals of the second processing unit 5, the differential delay between the luminance signal Y and the color difference signals C_R and C_B generated by the CCD image sensors 1R, 1G and 1B of the image pickup unit 1 may be compensated to assure high quality analog picture signals.

Besides, with the present digital cam corder, since the second digital processing unit 5 has the function of bidirectional rate conversion between the f_{s1} rate related data rate and the f_{s2} rate related data rate, and generates f_{s2} rate related data rate digital luminance and digital color difference signals, entered from the second delay compensation circuit 54Y during external input mode, and the f_{s1} rate related output data rate signals Y, C_R and C_B, having the same group delay as that of the signals Y, C_R and C_B, outputted from the first digital processing unit 4, to supply the generated signals to the A/D converting unit 61 of the signal processing unit 6, the differential delay between the luminance signal Y and the color difference signals C_R and C_B may be compensated even during the external input mode to assure high quality analog picture signals.

With the solid-state image pickup apparatus according to the present invention, the picture signals outputted from at least one solid-state image sensor driven at the f_{s1} rate are digitized at the f_{s1} rate at a predetermined phase by a predetermined A/D converting unit and at least the digital luminance signals Y and two digital color chrominance signals C_R and C_B are generated from the digitized pickup data by the first digital processing unit operated at the f_{s1} related clock rate, so that high quality picture signals free of beat interference may be produced. Besides, since the f_{s1} related input data rate signals Y, C_R and C_B are converted by the second digital processing unit into signals Y, C_R and C_B having the f_{s2} related output data rate, the digital picture signals having the D-1 standard clock rate or other clock rate may be produced using a standard CCD image sensor.

With the solid-state image pickup apparatus according to the present invention, the second digital processor performs bandwidth limitation of the input data rate signals Y, C_R and C_B, generated by the first digital processing unit, at the output data rate of $2f_{s1}$, f_{s1} and f_{s1}, by half band filters having the passbands of $f_{s2}/2$, $f_{s2}/4$ and $f_{s2}/4$, while performing the rate conversion of from $2f_{s1}$ to f_{s2}, f_{s1} to $f_{s2}/2$ or $f_{s2}/4$ and from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$ for outputting the low order linear phase finite impulse response to suppress the high order sideband component in the vicinity of $n\times 2f_{s1}$, $n\times f_{s1}$ and $n\times f_{s1}$, n being a positive integer, in the down-sampled form at f_{s2}, $f_{s2}/2$ or $f_{s2}/4$, $f_{s2}/2$ or $f_{s2}/4$. Besides, the bandpass roll-off characteristics of the rate converting filter are compensated by the characteristics of the half-band filter. This enables the rate conversion operation to be performed reliably by the second digital processing unit of a simplified construction.

In the solid-state image pickup apparatus according to the present invention, the rate converting filter for performing the rate conversion on the signals limited in bandwidth by the half band filters has an impulse response of an integer coefficient having at least one zero point $n\times 2f_{s1}$, $n\times f_{s1}$ and $n\times f_{s1}$ and two zero points in the vicinity thereof, and may be constructed by a plurality of multipliers.

In the solid-state image pickup apparatus according to the present invention, the half band filter for bandwidth-limiting the input data rate signals Y, C_R and C_B, generated by the first digital processing unit, may be constructed in a simple manner by the product of partial filters constructed by integer coefficients.

In addition, with the solid-state image pickup apparatus according to the present invention, since the image pickup signals, outputted from plural solid-state image sensors, arranged in the color-separating optical system in accordance with the spatial pixel shifting method so as to be driven at the f_{s1} rate, are digitized by the A/D converting unit at the f_{s1} rate, at a predetermined phase, the digital luminance signals Y ($2f_{s1}$) having the rate $2f_{s1}$ and the digital color difference signals C_R (f_{s1}) and C_B (f_{s1}) having the rate equal to f_{s1} are generated by the first digital processing unit so as to be processed by the second digital processing unit with rate conversion of from m to n, where m and n are positive integers, for generating the digital luminance signal Y (f_{s2}) having the rate of $f_{s2}=f_{s1}\cdot n/m$ and the $f_{s2}/2$ clock rate digital color difference signals C_R (f_{s2}) and C_B (f_{s2}), so that high TMF high quality digital picture signals may be generated without producing beat interference.

What is claimed is:

1. A solid-state image pickup apparatus comprising:

a solid-state image sensor for providing image pickup signals at a predetermined data rate of f_{s1},

analog-to-digital converting means coupled to said solid-state image sensor for digitizing said image pickup signals at a clock rate equal to f_{s1} for outputting digital image pickup signals,

first digital processing means supplied with said digital image pickup signals for providing at least a digital luminance signal having a data rate equal to $2f_{s1}$ and two digital color difference signals each having a data rate equal to f_{s1},

recording/reproducing means interfaced with a clock rate related to f_{s2},

second digital processing means coupled to said first digital processing means and said recording/reproducing means, said second digital processing means converting the data rate of said digital luminance signal supplied from said first digital processing means to a data rate equal to f_{s2} for outputting a rate-converted digital luminance signal to said recording/reproducing means for the recording mode.

2. A solid state image pickup apparatus according to claim 1, further comprising a signal processing means supplied with said digital luminance signal and the two digital color difference signals for generating output signals, said second digital processing means for converting the data rate of said digital luminance signal supplied from said recording/reproducing means to a data rate equal to $2f_{s2}$ for outputting a converted digital luminance signal and supplying said rate-converted digital luminance signal to said signal processing means in a playback mode.

3. The solid-state image pickup apparatus according to claim 1, wherein said second digital processing means is operable to set a plurality of data rate conversion ratios.

4. The solid-state image pickup apparatus according to claim 1, wherein said second digital processing means comprises:

a filter functioning as a Nyquist filter for the clock rate of f_{s2} on the digital luminance signals having the data rate of $2f_{s1}$, generated by said first digital processing means, for outputting digital luminance signals having a data rate of $2f_{s1}$, and

a rate converting filter for performing data rate conversion of from $2f_{s1}$ to f_{s2} on said digital luminance signals having a data rate of $2f_{s1}$,

said filter having constant characteristics and said rate-converting filter having a variable rate-converting ratio.

5. The solid-state image pickup apparatus according to claim 2, wherein said signal processing means comprises:

digital-to-analog converting means for converting the digital luminance signal and the two digital color difference signals into an analog luminance signal and analog color difference signals, and

an analog encoder supplied with said analog luminance signal and analog color difference signals generated by said digital-to-analog converting means.

6. The solid-state image pickup apparatus according to claim 5 comprising:

delay compensation means in a luminance signal channel of said first digital processing means for compensating for a group delay caused by a low-pass filter adapted for bandwidth-limiting on the analog color difference signals in said analog encoder.

7. A solid-state image pickup apparatus comprising:

a solid-state image sensor for providing image pickup signals at a predetermined data rate of f_{s1},

analog-to-digital converting means coupled to said solid-state image sensor for digitizing said image pickup signals at a clock rate equal to f_{s1} to form digital image pickup signals,

first digital processing means supplied with the digital image pickup signals from said analog-to-digital converting means for providing at least a digital luminance signal having a data rate related to f_{s1} and two digital color difference signals each having a data rate related to f_{s1},

recording/reproducing means interfaced with a clock rate related to f_{s2},

second digital processing means coupled to said first digital processing means and said recording/reproducing means for converting the data rate of said digital luminance signal and the two color difference signals supplied from said first digital processing means to a data rate related to f_{s2} for generating the rate-converted digital luminance signal and the rate-converted color difference signals, said second digital processing means supplying the rate-converted digital luminance signal and the rate-converted digital color difference signals to said recording/reproducing means.

8. The solid state image apparatus according to claim 7, further comprising signal processing means supplied with said digital luminance signal and the two digital color difference signals for generating output signals, wherein said second digital processing means is coupled to said recording/reproducing means for converting the data rate of the digital luminance signals and the digital color difference signals supplied thereto by said recording/reproducing means to a data rate related to f_{s1} for generating the rate-converted digital luminance signals and the rate-converted digital color difference signals, said second digital processing means supplying said rate-converted digital luminance signals and said rate-converted digital color difference signals to said signal processing means.

9. The solid-state image pickup apparatus according to claim 8, wherein

the digital luminance signal and the two color difference signals generated by said first digital processing means are outputted via said signal processing means and supplied via said second digital processing means to said recording/reproducing means in a recording mode, and wherein

the digital luminance signal and the two digital color difference signals of a data rate related to f_{s2}, supplied from said recording/reproducing means, are supplied via said second digital processing means to said signal processing means in a playback mode, via which the signals supplied from said recording/reproducing means are outputted as playback signals.

10. The solid-state image pickup apparatus according to claim 8, wherein said signal processing means comprises digital-to-analog converting means.

11. The solid-state image pickup apparatus according to claim 8, wherein said first digital processing means produces the digital luminance signal having a data rate of $2f_{s1}$ and said second digital processing means performs data rate conversion of from $2f_{s1}$ to f_{s2} on the digital luminance signal having the data rate of $2f_{s1}$ in a recording mode.

12. The solid-state image pickup apparatus according to claim 11, wherein said second digital processing means performs data rate conversion of from f_{s2} to $2f_{s1}$ on the digital luminance signal supplied from said recording/reproducing means in a playback mode.

13. The solid-state image pickup apparatus according to claim 8, wherein said first digital processing means produces the digital luminance signal having a data rate of $2f_{s1}$ and the two digital color difference signals, each having the data rate of f_{s1} in a recording mode, and wherein said second digital processing means performs data rate conversion of from $2f_{s1}$ to f_{s2} on the digital luminance signal having the data rate of $2f_{s1}$ and data rate conversion of substantially from f_{s1} to $f_{s2}/2$ on said two color difference signals having the data rate of f_{s1}.

14. The solid-state image pickup apparatus according to claim 13, wherein said second digital processing means performs data rate conversion of from f_{s2} to $2f_{s1}$ on the digital luminance signal having the data rate equal to f_{s2} and data rate conversion of substantially from $f_{s2}/2$ to f_{s1} on the two digital color difference signals having the data rate equal to $f_{s2}/2$ in a playback mode.

15. The solid state image apparatus according to claim 7, further comprising signal processing means supplied with said digital luminance signal and the two digital color difference signals for generating output signals, wherein said second digital processing means coupled to said signal processing means and said recording/reproducing means for converting the data rate of the digital luminance signals and the digital color difference signals supplied thereto by said recording/reproducing means to a data rate related to f_{s2} for generating the rate-converted digital luminance signals and the rate-converted digital color difference signals, said second digital processing means supplying said rate-converted digital luminance signals and said rate-converted digital color difference signals to said signal processing means.

16. The solid-state image pickup apparatus according to claim 15, wherein said first digital processing means produces the digital luminance signal having a data rate of $2f_{s1}$ and said second digital processing means performs data rate conversion of from $2f_{s1}$ to f_{s2} on the digital luminance signal having the data rate of $2f_{s1}$ in a recording mode.

17. The solid-state image pickup apparatus according to claim 16, wherein said second digital processing means performs data rate conversion of from f_{s2} to $2f_{s2}$ on the digital luminance signal supplied from said recording/reproducing means in a playback mode.

18. The solid-state image pickup apparatus according to claim 17, wherein said signal processing means comprises digital-to-analog converting means for converting, for the recording mode, the digital luminance signal having a data

rate of $2f_{s1}$, produced by said first digital processing means, into analog signals, which are outputted, said digital-to-analog converting means converting, for the playback mode, the digital luminance signal having a data rate of $2f_{s2}$, produced by said second digital processing means, into analog signals, which are outputted.

19. The solid-state image pickup apparatus according to claim 15, wherein said first digital processing means produces the digital luminance signal having a data rate of $2f_{s1}$ and the two digital color difference signals, each having the data rate of f_{s1} in a recording mode, and wherein said second digital processing means performs data rate conversion of from $2f_{s1}$ to f_{s2} on the digital luminance signal having the data rate of $2f_{s1}$ and data rate conversion of substantially from f_{s1} to $f_{s2}/2$ on said two color difference signals having the data rate of f_{s1}.

20. The solid-state image pickup apparatus according to claim 19, wherein said second digital processing means performs data rate conversion of from f_{s2} to $2f_{s2}$ on the digital luminance signal having the data rate equal to f_{s2} and data rate conversion of substantially from $f_{s2}/2$ to f_{s2} on the two digital color difference signals having the data rate equal to $f_{s2}/2$ in a playback mode.

21. The solid-state image pickup apparatus according to claim 20, wherein said signal processing means comprises digital-to-analog converting means for converting, for the recording mode, the digital luminance signal having the data rate of $2f_{s1}$ and the two digital color difference signals having the data rate of f_{s1}, produced by said first digital processing means, into analog signals, which are outputted, said digital-to-analog converting means converting, for the playback mode, the digital luminance signal having the data rate of $2f_{s2}$ and the two digital color difference signals having the data rate of f_{s2}, produced by said second digital processing means, into analog signals, which are outputted.

22. The solid-state image pickup apparatus according to claim 20, wherein, said second digital processing means comprises a filter operated, for the recording mode, at a clock rate of $2f_{s1}$ and functioning as a Nyquist filter for the clock rate of $2f_{s1}$ on the digital luminance signals having the data rate $2f_{s1}$ generated by said first digital processing means, said filter being operated, for the playback mode, at clock rates of $2f_{s2}$ and f_{s2} on the digital luminance signals and the digital color difference signals, respectively, and presenting the same frequency characteristics as in the recording mode, and

a rate converting filter connected to said filter for performing data rate conversion of substantially from $2f_{s1}$ to f_{s2} and data rate conversion of substantially from f_{s1} to $f_{s2}/2$ on the digital luminance signals supplied via said filter and on the two digital color difference signals, for the recording mode, respectively, said filter being used both for the playback mode and for the recording mode.

23. A solid-state image pickup apparatus comprising:

a plurality of solid-state image sensors for providing image pickup signals at a predetermined data rate of f_{s1},

analog-to-digital converting means coupled to said image sensors for digitizing said image pickup signals at a clock rate equal to f_{s1} for forming digital image pickup signals,

first digital processing means supplied with said digital image pickup signals from said analog-to-digital converting means for providing at least a digital luminance signal having a data rate equal to $2f_{s1}$ and two digital color difference signals each having a data rate equal to f_{s1},

second digital processing means coupled to said first digital processing means for converting the data rate of said digital luminance signal and the two digital color difference signals from M to N, M and N being natural numbers, for providing a digital luminance signal having a data rate equal to f_{s2}, where $f_{s2}=2f_{s1}\cdot N/M$, and two color difference signals having a data rate substantially equal to $f_{s2}/2$, said second digital processing means having a half band filter, said half band filter having a passband in a range of from 0 to $f_{s2}/2$ for the digital luminance signal and a passband in a range of from 0 to $f_{s2}/4$ for the digital color difference signals, and a rate converting filter supplied with outputs of said half band filter for down-sampling the digital luminance signal at a data rate equal to f_{s2} and for down-sampling the two color difference signals at a data rate equal to $f_{s2}/2$, for suppressing higher order sideband components close to $N\times 2f_{s1}$, N being a natural number.

24. A solid-state image pickup apparatus according to claim 1, wherein one of said image sensors is arrayed with a spatial shift equal to one-half the pixel arraying pitch with respect to the remaining image sensors.

25. A solid-state image pickup apparatus comprising:

a solid-state image sensor for providing image pickup signals at a data rate equal to f_{s1},

analog-to-digital converting means coupled to said solid state image sensor for digitizing said image pickup signals at a data rate equal to f_{s1} at a predetermined phase to form digital image pickup signals,

first digital processing means operated at a clock rate related to said data rate of f_{s1} for generating, from said digital image pick-up signals, at least a digital luminance signal having a data rate related to f_{s1} and two digital color difference signals having a data rate related to f_{s1},

second digital processing means for converting said digital luminance signal having a data rate related to f_{s1} and said two digital color difference signals having a data rate related to f_{s1} into a digital luminance signal having a data rate related to f_{s2} and two digital color difference signals having a data rate related to f_{s2}, respectively,

said second digital processing means having a half band filter having a passband of $f_{s2}/2$ for said digital luminance signal from said first digital processing means having a data rate related to f_{s1}, with the data rate being $2f_{s1}$, and a passband of $f_{s2}/4$ for said two digital color difference signals from said first digital processing means having a data rate related to f_{s1}, with the data rate being f_{s1}, and a rate converting filter for performing data rate conversion of from $2f_{s1}$ to f_{s2} on the digital luminance signals supplied via said half band filter and down-sampling a low order linear phase finite length impulse response sufficient to suppress higher order sideband components in the vicinity of $n\times 2f_{s1}$, where n is a positive integer, at a down-sampling rate of f_{s2} for outputting down-sampled impulse response, said rate converting filter also performing data rate conversion of from f_{s1} to $f_{s2}/2$ or $f_{s2}/4$ on said two digital color difference signals supplied via said half band filter and down-sampling a low order linear phase finite length impulse response sufficient to suppress higher order sideband components in the vicinity of $n\times f_{s1}$, where n is a positive integer, at a down-sampling rate of $f_{s2}/2$ or $f_{s2}/4$ for outputting down-sampled impulse response.

26. The solid-state image pickup apparatus according to claim 25, wherein said half band filter has characteristics

which compensate for roll-off characteristics of said rate converting filter.

27. The solid-state image pickup apparatus according to claim 26, wherein said rate converting filter has at least one zero point at $n\times 2f_{s1}$ for said digital luminance signal and at $n\times f_{s1}$ for said two digital color difference signals, said rate converting filter also having each two zero points in the vicinity thereof.

28. The solid-state image pickup apparatus according to claim 25, wherein said rate converting filter comprises a plurality of multipliers.

29. The solid-state image pickup apparatus according to claim 25, wherein said half band filter comprises a product of partial filters each constituted by integer coefficients.

30. A solid state image pickup apparatus comprising:

a plurality of solid-state image sensors for providing image pickup signals at a predetermined data rate of f_{s1}, at least one of said image sensors being arrayed with a spatial shift equal to one-half the pixel arraying pitch with respect to the remaining image sensors,

analog-to-digital converting means for digitizing said image pickup signals at a clock rate equal to f_{s1} for forming digital image pickup signals,

first digital processing means supplied with said digital image pickup signals from said analog-to-digital converting means for providing at least a digital luminance signal having a data rate equal to $2f_{s1}$ and two digital color difference signals each having a data rate equal to f_{s1}, and

second digital processing means coupled to said first digital processing means for converting the data rate of said digital luminance signal and the two digital color difference signals from M to N, M and N being natural numbers, for providing a digital luminance signal having a data rate equal to f_{s2}, where $f_{s2}=2f_{s1}\cdot N/M$, and two color difference signals having a data rate substantially equal to $f_{s2}/2$, and

third digital processing means coupled to said first digital processing means for processing said digital luminance signal and the two digital color difference signals to output processed signals to an external device.

31. The solid-state image pickup apparatus according to claim 30, wherein said second digital processing means includes a half band filter having a passband in a range of from 0 to $f_{s2}/2$ for the digital luminance signals and a passband in a range of from 0 to $f_{s2}/4$ for the digital color difference signals, and a rate converting filter supplied with outputs of said half band filter for down-sampling the digital luminance signal at a data rate equal to f_{s2} and for down-sampling the two color difference signals at a data rate equal to $f_{s2}/2$, for suppressing higher order sideband components close to $N\times 2f_{s1}$, N being a natural number.

32. The solid-state image pickup apparatus according to claim 30, wherein said second digital processing means is operative to set a plurality of rate conversion ratios.

33. The solid-state image pickup apparatus according to claim 30, further comprising recording/reproducing means interfaced with said second digital processing means at a clock rate related to fs_2.

34. The solid-state image pickup apparatus according to claim 30, wherein said third digital processing means includes digital/analog conversion means for converting said digital luminance signal and the two digital color difference signals to an analog luminance signal and to analog color difference signals, respectively.

35. The solid-state image pickup apparatus according to claim 30, wherein said second digital processing means is operative to down-convert the data rate of said digital luminance signal and the two digital color difference signals from M to N.

* * * * *